

EDITORIAL

The underutilized resources in the lowland wet zone forests of Sri Lanka and untapped Indigenous knowledge of peripheral households

A.L. Ranawake

Department of Agricultural Biology, Faculty of Agriculture, University of Ruhuna, Kamburupitiya, Sri Lanka

Abstract: Biological diversity and cultural diversity have been identified as interdependent factors by UNESCO “Culture for the 2030 Agenda”. Biological diversity determines the livelihood of the inhabitants. The contribution of inhabitants to conserve or manage the habitat sustainably is highly recognized by the world heritage convention. Minimizing waste, avoiding chemicals, selecting natural and healthier products, and recyclability are the five sustainability goals in trend. Ecological sustainability is the key feature of the communities living in their natural habitats. Indigenous knowledge of the people who lived in a specific area for generations is an underutilized resource for the sustainable management of the ecological system. Data centrism, carbon offsetting, and going for green products are new concepts of the century. These concepts were often applied by the local people who lived closer to lowland tropical forests in Sri Lanka. Gathering information on indigenous knowledge and identifying the diverse materials used by the indigenous people will be a reference library for future sustainable utilization, management, and conservation of lowland tropical forests. The present work describes indigenous knowledge as revealed by the local people who live closer to lowland tropical forests. The information is mainly focused on agriculture-related themes, namely food (mushrooms, aquatic and terrestrial leaves, wild fruits, aquatic molluscs), wood, vines, and leaves for production purposes (materials for housing, wood for specific purposes, leaves for weaving), natural substances (oils, wax, resins, dyes, and toxic substance gathered from the forests, their sources, and usage) and honey collection and animal rearing. This invites the scientific community to explore the untouched areas in the nutraceutical, pharmaceutical, ethnobotanical, phytochemical, and architectural fields within new trending concepts such as ecological sustainability, eco-friendly, low-waste food, functional food, carbon footprint offset, green building, eco-tourism, and tightening supply chain concepts.

Keywords: *Food and Wood, rain forests Sri Lanka, traditional knowledge.*

Introduction

Sri Lanka, the pearl of the Indian ocean is gifted with natural beauty, diverse climatic conditions, eye-catching topography, and multicultural societies. The multicultural societies evolved at different locations not only by religion or language but also by the resources available and the skills developed and passed on through generations. Continuous experience is very unique to the physical location where they lived; the people who lived in the coastal belt were involved in fisheries and coconut-related industries such as toddy tapping, copra drying and milling, and coir-based industries. The people who lived in areas with red clay deposits (ultisol) engaged

with digging clay, manufacturing pots on wheels, and burning them in kilns (Winslow, 1996). Besides those specific life patterns, the majority of the people were primarily engaged with agricultural-based production systems throughout the country with some location-specific crops and animal breeds. Agriculture is a diverse sector and harnessing natural resources from forests has been well woven with the livelihood of the villagers involved with farming and animal rearing. Other than material supplements, forests are important for the conservation of water resources, carbon sequestration, and climate moderation in localized regions (Ranagalage *et al.*, 2020).

*corresponding author: lankaranawake@hotmail.com  <https://orcid.org/0000-0003-0517-9911>



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Forests spread over Sri Lanka are a treasure for the islanders to harvest a diverse array of products at no cost as a secondary dependence next to agriculture. Eight different forest types in different bioclimatic zones have been categorized in Sri Lanka (Greller, and Balasubramaniam, 1980). Bioclimatic zones of Sri Lanka have been categorized based on annual rainfall and vegetation (Survey Department of Sri Lanka, 2012). The lowland tropical rainforests extend from the coastal plains to 1000 m altitude with varying temperatures over 20 °C and an annual rainfall of more than 2500 mm without no moisture deficit period for the vegetation. Lowland tropical forests in Sri Lanka are very rich in biodiversity, but unfortunately, tropical forests are the most vulnerable forest type in the world (Senanayake, *et al*, 1977). The natural gift to the future, the biodiversity of the lowland tropical forests must be extensively studied and strictly conserved.

The entire livelihood of the ancient villagers on the periphery of lowland rainforests was interwoven with the natural resources, rainfall, and indigenous knowledge passed from one generation to the next. This article focuses on underutilized resources and indigenous knowledge of the villagers who gathered materials from the forests and who had known the rhythm of nature by instinct. The objective of this article is to discuss the resources of lowland forests as utilized by the households in the peripheral villages of Sinharaja in Sri Lanka since this connection seems to have been lost in the last few decades. Exposing such a treasure of knowledge will motivate the scientific community to dissect the underlying scientific basis of the practices of the villagers in diverse areas to reveal the ways to utilize the diverse resources, integrate them with new techniques, and streamline the production processes to minimize the cost of input and to avoid unnecessary disturbances for the ecosystem.

What they gathered from lowland tropical rainforests?

Food; Mushrooms, aquatic green leaves, wild fruits, and aquatic mollusks

The demand for functional food in the new world is very high due to the increasing cost of health services and many other factors. Rather than eating tastier, available, seasonal, or familiar food, functional food targets health-promoting foods that are enriched with physiologically active compounds (Milner, 2000). Traditional foods are closely functional by their description as “foods for specified health uses” (Milner, 2000).

Mushroom-based dietary supplements are a novel trend in the modern pharmaceutical industry. Mushrooms have been identified as a nutraceutical with unique substances for human health (Wasser, *et al.*, 2000). There are many vernacular names for mushrooms in Sri Lanka. “*Hathu*” is the general term in the Sinhala language to refer to fruiting bodies of fungi, and picking mushrooms is one of the purposes of the villagers to visit the lowland forests. There are two types of mushrooms: wood decomposing mushrooms and substrate decomposing mushrooms. There are distinct types of wood decomposing mushrooms, and they emerge at specific ages of the decaying process of the wood. *Lena-hathu* (*Schizophyllum commune*) is the earliest to appear on the decaying logs. When the decomposition continues *Kandha-hathu* (*Lentinus subnudes*) starts to grow on the log. Unlike *Lena-hathu* which is sessile, *Kandha-hathu* has a small stalk. At the next stage of the decaying process of the log, a fleshy, brown and watery mushroom named *Thelka-hathu* or wood-ear mushroom (*Auricularia auricula* or *Auricularia polytricha*) emerges. According to the villagers, these mushrooms are not edible. However, both *A. auricula* and *A. polytricha* are popular edible mushroom types in other countries and have been valued as a treatment for oxidative stress ailments (Xiang *et al* 2021). A protocol for the domestication of the red-ear mushroom (*A. Auricularia*) has been introduced as a newly identified mushroom type (Bandara, *et al.*, 2017). This emphasizes that some countries with fast-growing food industry such as Thailand are still attempting to domesticate some forms of mushrooms. A golden-reddish, round-headed mushroom with about a 2.5 cm long stalk named *Kekiri-hathu* (*Amanita muscaria*), appears after *Thelka-hathu* on decaying logs. *Amanita muscaria* is not edible according to the villagers. It has been reported that visual and auditory hallucinations are evoked after eating *Amanita muscaria* (Satora, *et al.*, 2005). At the end of the decaying process of the log, *Kanamediri-hathu* (*Mycena*) starts growing. *Mycena* is sessile and luminous at night due to luciferin. *Mycena* is under investigation for bioluminescence and exhibition since it is attractive at night (Niitsu, and Hanyuda, 2000). *Mycena* has been intensively studied to understand the synteny and lineage of bioluminescence throughout the fungal evolution (Ke *et al.*, 2020). Light-weighted woods are good for mushroom production, and Mango (*Mangifera indica*) logs are the best to collect those edible mushrooms. Growing mushrooms on the logs are popular for home gardening, but not for commercial

production since it records a poor yield than using sawdust as a substrate (Freyand Heath, 2020). However, this is the era in which people are mindful of eco-friendly production, sustainability, carbon offsetting, and green products. Argo-forestry is an art, and mushroom production in agroforestry is practised in other countries (Dahl *et al* 2008a) though it's not popular in Sri Lanka.

Soil characteristics and weather prerequisites for fructification of edible mushroom, *Phellorinia* in the Thar desert were extensively studied. However, attempts to domesticate it by providing the same conditions artificially have failed (Dahl *et al* 2008b). It was suggested by Doshi and Bohra (2000), that leaching out of organic matter is needed for *Phellorinia* for fructification. A group of Japanese scientists (Sato *et al* 2012) has been observing around 12,000 counts in 668 species of two different fungal types, Ectomycorrhiza (fungi depend on roots) and Saprotrophs (fungi depend on decaying organic matter) for thirty years to understand the relationship between fungal phenology and climatic factors and concluded that the fructification of Ectomycorrhiza fungi is seasonal, but litter decomposing fungi have no seasonal fructification. They suggest that carbohydrate availability for the fungi decides fructification. These findings explain that the phenology of wood decomposing or substrate decomposing fungi is yet to be revealed in terms of temperature, humidity, and rainfall since it is highly specific.

“*Indalolu-hathu*” (*Termitomyces eurhizus*) is a somewhat bigger mushroom type with braiding around the stalk at its distal end, which demarcates the detachment of the head of the fruiting body from the stalk. *Indalolu-hathu* emerges from the subterranean termite colonies. Subterranean termites find the appropriate humid conditions deep underground inside the mound. There is a soft, spongy, and wood-based fungal comb inside the termite mound. Half-digested wood by the termite saliva is said to be the building material of the fungal comb. The fungal comb is a multi-functional structure that absorbs extra water vapour produced by the termites inside the mound, and it emits water into the mound once the mound dries off. Further, the fungal comb is a protected hideout for the immature termites to live in and the comb itself is a mineral-rich food for the immature termites to feed on (Noor, and Uddin, 2010). The fungus has a symbiotic relationship with the termites inside the mound (Batra, & Batra, 1979). A termite mound is a good shelter for the fungus and in return, fungus helps digestion of wood and organic matter providing food for the termites. Further, termite colonies are

congested and produce a large amount of CO₂. Termite mound has a good architectural design to pass the gases out through the underground channels. It provides the best hot and wet environment for *Indalolu-hathu* to grow well and emerge from the termite mound. Villagers harvest *Indalolu-hathu* on and around the termite mounds in the lowland forests. *Indalolu-hathu* is also visible just before the rain. A Norwegian team of researchers has developed a statistical model considering the correlation between fructification and weather data and found that cloud coverage of 3-5 weeks before fructification had a strong correlation with fructification, but the correlation of rainfall data and temperature with fructification was negligible (Dahl *et al.* 2008a).

Olu-weli-hathu (*Termitomyces* spp.) spreads as patches and villagers believe in finding seven patches in the vicinity. *Heen-weli-hathu* (*Termitomyces microcarpus*) is smaller than *Maa-weli-hathu* with a 4-5 cm long stalk and could be seen in sandy soils. *Puwak-bada-hathu* and *Indalolu-hathu* are similar in their structure with a 15-18 cm long stalk. *Puwak-bada-hathu* is not edible. *Kaila-hathu* is the same in appearance and size as *Puwak-bada-hathu*, but the outer surface of the fruiting body is brownish with a bradding and *Kaila-hathu* is also not edible. Scientific names of *Puwak-bada-hathu*, and *Kaila-hathu* are not confirmed.

Ooru-hathu (*Lentinus giganteus*) is a wood decomposing fungus. The diameter of the fruiting body is around 10 cm. Usually, 4-5 fruiting bodies could be seen at one location. *Diyathaliya* (*Mastixia tetrandra*) and *Albesia* (*Albizia julibrissin*) wood are the best substrates for *Ooru hathu*.

Athuru-hathu (*Agaricus fulvoalbus*) has two other synonyms; *Muukalan-hathu*, *Pus-hathu*. *Athura* and *Muukalana* are synonyms for the forest in the Sinhala language. *Athuru-hathu* is brown in colour. The well-grown *Athuru-hathu* is around 20 cm in diameter with a 15 cm stalk and the smaller ones are around 5-8 cm in diameter. During the fruiting time, the whole area is covered by different-sized fruiting bodies which is an impressive, rare view in the forest. Around 50-60 kg of *Athuru-hathu* can be harvested from one location during the fruiting season. Unlike other mushrooms, *Athuru-hathu* is not destroyed by pests and under dry conditions, fruiting bodies appear over a period of one month. However, in the rainy season, the fruiting body perishes soon. Before the fruiting body of *Athuru-hathu* emerges, the fungal mycelia densely spread around 4-5 m diameter surface area and around 15 cm deep under the drying

and decaying leaves. The soft soil texture and spongy nature of the ground are clues for the appearance of *Athuru hathu* soon in the area. January is a dry month in lowland forests. With the onset of rain, fungal mycelia start growing and April and May are the months to harvest *Athuru-hathu* from the lowland forests. Ancient villagers used to visit the places where there is a potential to find *Athuru-hathu* during the fruiting season and sometimes stayed several days deep in the forest until they appeared. Villagers engage in rattan work in temporary shelters in the forest until the appearance of *Athuru-hathu*. The huge diversity that exists in edible mushrooms in lowland forests should be systematically evaluated considering their taxonomical differences. The physico-chemical properties of the substrates should be analyzed for the optimization of the growth conditions for domestication. The active compounds of different mushrooms must be chemically analyzed. A long list of edible mushroom species has been published by Thawthong *et al.*, (2014). A large number of species are being produced on a mass scale due to consumer demand worldwide (Sharpe *et al.*, 2021). Despite the vast diversity of edible mushrooms in Sri Lanka, domestication or year-round production techniques have not been developed yet. World mushroom production highly depends on temperate mushroom species, though the growth rate of tropical mushrooms is greater than that of temperate species (Thawthong *et al.*, 2014). Mushroom cultivation is eco-friendly, and several waste materials can be easily converted into a productive substrate for mushroom spawns (Chukwurah, *et al.*, 2012; Yang, *et al.*, 2016). Further, the spent mushroom substrate can also be reused for the production of enzymes (cellulase, hemicellulase, xylanase, laccase, lignin peroxidase), animal feed, energy, and compost (Hanafi, *et al.*, 2018). Mushroom is a good substitution for animal-based, high-priced, high-carbon, and water footprinted protein sources. At this crucial time when Sri Lankans are experiencing import restrictions, domestication followed by mass production of mushrooms will be important. Studying the natural habitats of seasonal, non-domesticated mushroom species, and developing protocols for inducing fructification to overcome seasonal fruiting habit is essential for the success of this industry (Fig. 1).

Edible aquatic and terrestrial leaves

Edible aquatic plants found in the lowland rainforest regions of Sri Lanka are *Kekatiya* (*Aponogeton crispus*), *Mudamahana* (*Sphaeranthus indicus* L.), *Jabara* (*Eichhornia crassipes*), *wil-gahala* (*Colocasia esculenta*), *Miyena-koku* (*Acrostichum esculentum*), and *Karan-koku* (*Acrostichum aureum*

L.). These are good for diabetes, tumors, and infections. *S. indicus* is used to treat epilepsy. *Napiriththa* (*Hibiscus surattensis*) and *Kabarossa* (*Smilax zeylanica*) are terrestrial plants; immature leaves are edible. *Kabarossa* immature leaves are used for treating ulcers and diarrhoea.

Fifty chemical compounds have been extracted from *A. crispus*, and a long list of diseases for which the plant is used has been concluded (Chougule, *et al.*, 2022). Thrombolytic activity of *A. crispus* and *A. rigidifolius* has been confirmed using aqueous extracts (Sarveswaran, *et al.*, 2021). *A. crispus* has been used as a treatment for snakebite in Ayurveda (Dharmadasa, *et al.*, 2016). *S. indicus* is used for diabetes and this has been clinically proven to be effective (Prabhu *et al.* 2008). *S. indicus* is also used for epilepsy and mental illness. The effect of phytochemicals of *S. indicus* on nerve function has been discussed (Galani *et al.* 2010) and three new eudesmanoids have been isolated from it (Pujar *et al.* 2000). These compounds are closely related to the neuro system (Asakura, *et al.*, 2000). Anti-bacterial and anti-inflammatory properties of *A. aureum* L. (Wu, *et al.*, 2018) and anti-diarrhoea properties (Sultana, *et al.*, 2018) of *S. indicus* have already been well demonstrated (Fig. 2).

Wild fruits and vegetables

Popular wild fruits in the wet zone rainforest region of Sri Lanka include *Mora*, which consists of different species; mas-mora (*Adenanthera bicolor* Moon), *Eta-mora* (*Crtptocarya membranaceae* Thw.), and *Gal-mora* [*Prunus walkeri* (Wight) Kalkman]. The flesh is thick in *Mas-mora*, and the seed is bigger in *Eta-mora*. *Gal-mora* is small and similar to *eta mora*. A wild type of curry leaves plant (*Wal-karapuncha*) that has larger whitish fruits when ripe are edible and tasty unlike domesticated curry leaves - *Karapuncha* (*Muraya koenigii*). *Kiriwel* (*Gynochthodes umbellate*) is a large and tasty wild fruit. The mature stem of *Kiriwel* is about 15 cm in diameter. *Goda-wara* (Scientific name is not available) is believed to be a wild type of ash gourd with an invasive type of vine. However, monkeys never leave any fruit of *Kiriwel* or *Goda-wara* since they eat immature fruit. *Goda-wara* is cooked as a vegetable too when it is not ripened.



Lena-hathu (*Schizophyllum commune*)



Kandha-hathu (*Lentinus sub nudes*)



Thelka-hathu (*Auricularia auricula* or *A. polytricha*)



Kalamediri-hathu (*Mycena chlorophos*)



Indalolu-hathu (*Termitomyces eurhizus*)



Oluweli-hathu (*Termitomyces* spp)



Heenweli-hathu (*Termitomyces*)



Ooru-hathu (*Lentinus giganteus*)



Athuru-hatu (*Agaricus fulvoalbu*)

Figure 1: Morphological features of some of the mushroom species found in wet zone rain forests in Sri Lanka



Kekatiya (*Aponogeton*



Mudamahana (*Epaltes divaricata* Cass.)



Napiriththa (*Hibiscus hispidissimus* Griff.)



Kabarossa (*Smilax zeylanica*



Jabara (*Eichhornia crassicaulis*)



Wilgahala (*Colocasia esculenta*)



Miyenakoku (*Diplazium esculentum* (Retz.) Sw



Kerankoku (*Acrostichum aureum*)



Paththarakoku (*Blechnum orientale* L.)



Kohila (*Lasia spinosa*)

Figure 2: Edible aquatic and terrestrial leaves

Some of the wild fruits found in forests in Sri Lanka have been listed (Pushpakumara *et al.*, 2016). The list must be updated including these types of fruits and an effort must be taken to domesticate them. Stem bases of *Wewel* (*Calamus spp.*) and *Katu-kithul* (*Oncosperma fasciculatum*) are also cooked as curries. However, excessive harvesting of the stem bases for consumption badly reduces the plant population.

Beraliya (*Shorea oblongifolia*) fruit is good for diabetes and consumed as pittu, boiled *Beraliya* with coconut, or as a curry. *Beraliya* is soaked in water overnight and washed out several times before cooking. *Hal* (*Vateria copallifera*) fruit is used to prepare pittu or helapa. *Hal* fruits are grated using a dented tin cover and the grated fruit is kept in a water stream overnight to wash out by the flowing water before cooking (Fig. 3).

Aquatic mollusks

Aquatic mollusks attached to stones in waterways are good for infants suffering from malnutrition, referred to as “*giraheniya*” in rural societies. Aquatic animal source foods (AASF) are rich in docosahexaenoic acid (DHA), choline, and vitamin B12 needed to overcome anaemia and childhood stunting (Iannotti, *et al.*, 2021). Further, mollusks are rich in antioxidants that are needed to neutralize cancer-causing free radicals. Another two elements found in mollusks are zinc and selenium. Zinc is important to lower inflammation of stomach and infections while selenium is important to reduce oxidative stress to boost immunity (McKenzie *et al.* 2009; Brummell *et al.* 2011; Boldrin *et al.*, 2013).

Forest products as raw material for house construction

Clay walls and the roof thatched with different leaves were the common housing type in ancient Sri Lanka. Materials for house construction were collected from the forests. *Mandoran* (*Vatica paludosa*) is the best timber for the strongest ridge beams, and *Ubberiya* (*Carallia calycinensis*) is second only to *Mandoran*. *Hal* (*Vateria copallifera*), *Domba* (*Calophyllum inophyllum*), *Dabu* (*Syzygium gardneri*), and *Welipiyanna* (*Anisophylla cinnamomoides*) are used for tie-beams.

Bandhura vine (*Nepenthes distillatoria*) is used to construct the roof trusses. The beams of the trusses were tied with the *Bandhura* vine. Three branches of *Bata* (*Ochlandra stridulata*) leaves were inserted into the space between *Bandhura* vine of the truss four inches apart. This technique is called *Nam-kireema*.

The heaps of *Pamba* vine (*Lygodium scandens*) were placed on the top of the *Bata* leaves to prevent possible movement from the wind. *Iluk* (*Imperata cylindrica*) leaves and *Beru* leaves (*Agrostistachys coriacea*) were also used for thatching purposes. *Beru* has 45-50 cm long leaves, and they can be seen as patches in the forest, convenient for bulk harvesting. *Beru* leaves were inserted one after another with a bunch of *Bata* leaves on the roof. This type of roof was durable for around 7-8 years under cyclic dry and wet seasons in the year. *Beru* leaves are durable for around ten years on the roof. The smoke produced by the wooden hearth was the best conditioning for the durability of the roof. Though the thatched roof is a good habitat for the reptiles by its appearance, smoking kept the pests and reptiles away from the thatched roof. *Thel-karawala* (*Bungarus ceylonicus*), *Mal-karawala* (*Rhabdophis ceylonensis*), and *Maa-pila* (*Boiga ceylonensis*) are the common poisonous snakes that can harm villagers in the wet zone forests of Sri Lanka. However, continuous cooking, especially treacle production using firewood was the reason to keep the reptiles out of the roof.

The stem of *Beru* is 2.5-5 cm in diameter and ideal for the handle of the eakle broom. Eakle broom is produced by keeping a coconut shell at the base of a bunch of eakles and weaving the base of the bunch with a thin rattan strip to spread coconut eakles.

Preparing clay walls needed *Bamboo* (*Bambusa vulgaris* Schrad), *Weraniaya* (*Hedyotis fruticosa* L.) or *Bata* (*Ochlandra stridula*). Inflorescence pedicels of *Kithul*, *Bandhura* vine (*Nepenthes distillatoria*) and *Weniwel/Ban* vine (*Coscinium fenestratum*) are used to bind the bamboo structure leaving 20×20 cm² inches holes. The holes between bamboo strips are called “*Mokoli*” and are filled with clay. Any soil without stones is used for clay and there is no need of transportation from region to region. The clay is seasoned by pressing by foot while mixing with additional water and leaving in a heap. After drying, seasoned clay becomes adequately harder than unseasoned clay. After filling the holes, a mixture of clay and cow dung slurry is used as a plaster. Plastering with cow dung and clay mixture prevents the bamboo from pest attacks. This mixture is called “*Demati*”. *Makulumeti* (Kaolinite) is whitish in colour and can be found at specific locations in paddy fields. *Makulumeti* is applied on *Demati* to get a pleasant light-colored appearance for the wall (Fig. 4). Clay is a good material for house construction over sand-cement mixed blocks since it certifies in-house thermal comfort.



Kahata (*Careya arborea*)

Kiriwel (*Ichnocarpus frutescens* (L.) W.T.Aiton)



Katu-kithul (*Oncosperma fasciculatum*)



Masmora (*Adenanthera aglaosperma* Alston)



Eta-mora (*Dimocarpus longan* ssp. *longan* var. *longan*)



Walkarapuncha (*Micromelum minutum* var. *ceylanicum* B.C.Stone)



Figure 3: Wild fruits and vegetables found in wet zone rain forests



Pamba (*Lygodium scandens*)



Badura (*Nepenthes distillatoria*)



Iluk (*Imperata cylindrica*)



Bata (*Ochlandra stridulathw*)



Una (*Bambusa vulgaris* Schrad. ex J.C.Wendl.)



Weraniya (*Hedyotis fruticosa* L)



Banwel/Weniwel (*Coscium fenestratum*)



Beru (*Agrostistachys coriacea*)

Figure 4: Forest products as raw materials for house construction

The physical and mechanical properties of cow dung on clay have been evaluated by high-tech approaches and the results revealed that the reaction of cow dung with clay (kaolinite) and fine quartz (sand) forms insoluble silicate amine, the material binds soil particles together. Besides this chemical property, fine fibers in cow dung physically prevent the formation of cracks on the surface of the clay and increase the water-resistance (Millogo, *et al.*, 2016). The antifungal and antibacterial properties of cow-dung slurry as a plastering material for walls and floors of clay houses were confirmed by examining *E.coli*, *Candida*, *Staphylococcus*, and *Pseudomonas* growth (Sushmita *et al* 2014). Shrinkage, sorptivity and strength of cow dung (Lekshmi *et al* 2020) and thermal comfort and water-resistant power of cow dung has been investigated (Bamogo, *et al.*, 2020).

Nowadays, the sector of sand and cement products consumes a large amount of energy. Demolition of such constructions adds heaps of waste to the environment that is not able to be fully recycled hence leaving wastes in the ecosystem. Wood, clay, and straw have been identified as the best materials for house construction over cement and steel. Cement production is responsible for 8% of CO₂ in the world (Cloete, *et al.*, 2020). Cement is being replaced by bails of straws in recent green building construction. Straw is a good insulation material to keep the room temperature lower inside the house which has been practiced by the villagers in ancient Sri Lanka. The house is constructed on top of a 46 cm tall, stoned foundation, and the space of the foundation is filled with sand and soil. Oils extracted from different seeds are mixed with the soil to prevent possible termite attacks.

Kithul palm (*Caryota urens*) and treacle production

Treacle production is done by evaporating floral sap of toddy palm and generally, 3-6 L of floral sap must be boiled and evaporated to produce one bottle of treacle. Usually, toddy tapping is done three times a day, and one palm can be harvested for 3-6 months continuously. Fresh floral sap is rich in sugars and is a good medium for microbial growth. Leaving floral sap at least for a few hours causes fermentation. Fermented floral sap is consumed as toddy, local alcohol, and leaving floral sap for a longer period produces vinegar.

Treacle production is purely a traditional process starting from the selection of a palm for good yield. The palms broader at the crown than at the base of the trunk are called female palms and are good for tapping. The palms with cylindrical trunks are called male

palms and will not give a good floral sap yield. The peduncle of the inflorescence is seasoned before tapping using a homemade mixture to increase the flow rate of floral sap. The seasoning mixture contains bird-chilli (*Capsicum frutescence*), Ginger (*Zingiber officinale*), Garlic (*Allium sativum*), pepper (*Piper nigrum*) and Alocasia (*Alocasia macrorrhizos*). The pieces of stem peel of *Hal* (*Vateria copallifera*) are kept in treacle to prevent fermentation and pieces of *Ankenda* (*Acronychia pedunculata*) leaves are used to prevent fermentation of floral sap, but *Ankenda* leaves can't be used for treacle or *Hal* peels can't be used for floral sap to prevent fermentation. Toddy is produced by inoculating floral sap with a pinch of inoculum for fermentation and *Kudametta* (*Fimbristylis dichotoma*) leaves can stop fermentation. Phyto-chemical analysis of *Kudametta* has demonstrated the insecticidal and antimicrobial activity of the leaf extract (Abdullah, *et al.*, 2021).

Anti-bacterial and anti-fungal activities of *Ankenda* leaf extract have been confirmed (Jayasinghe, *et al.*, 2006) for using the plant for wound healing in Ayurveda. The potential of the extract for ethnopharmacological uses due to the toxicity of the plant extract has been validated (Ratnayake, *et al.*, 2019). *Acronychia*-type acetophenones have been isolated from the bark of *Ankenda*, and the cytotoxic activities of the acetophenone dimers have been evaluated against prostate and melanoma human cancer, and the cytotoxic activity of the isolated compounds has been confirmed (Kouloura, *et al.*, 2012). The same inhibitory activities of the leaf and twig extract of *Ankenda* have been confirmed (Kozaki, *et al.*, 2014). (Fig. 5)

Use of wood by the villagers in wet zone forest area

Diverse wood species are utilized for diversified tasks by the villagers. *Domba* (*Calophyllum inophyllum*) wood is resistant to wringing, used to produce the axel and wheel of the bullock cart and plough. Now *Domba* wood is used to mount lorry decks and bodies. *Katukenda* (*Scolopia pusilla*), *Kaduru* (*Cerbera dichotoma* G.Lodd.) and *Kithul* (*Caryota urens*) wood is used for mortar, and the pestle is produced from *Milla* (*Vitex altissima*), *Jack* (*Artocarpus heterophyllus*), and *Kahata* (*Careya arborea*). *Milla* is also used for barbed wire fences. *Keta-kerella* (*Bridelia moonii*) and *Bombu* (*Sapphirberry* (*Symplocos cochinchinensis*)) are also good for fencing with barbed wires.



Kithul palm (*Caryota urens*)



Preparation of the pot and the palm for tapping



Tapping method



Fermenting toddy



Hal (*Vateria copallifera*)



Ankenda (*Acronychia pedunculata*)



Kudametta (*Fimbristylis dichotoma*)



Treacle production method (Left)

Jaggery production method (Right)

Figure 5: Kithul palm (*Caryota urens*) and treacle production

Timber of Jack (*Artocarpus heterophyllus*) and *Hedawaka* (*Chaetocarpus castanocarpus*) are good for wood carving. *Hedawaka* has a reddish wood, and latex can be seen in the peel. *Rukkathana* (*Alstonia scholaris*) wood is the premium timber for making masks. This wood is light to wear. Jack wood is the best for furniture, and *Burutha* (*Chloroxylon swietenia*) wood is selected for its colour gradient in its hardwood. Villagers use *Mahogany* (*Swietenia macrophylla*) as a second option for furniture making. *Milla* (*Vitex altissima*) is the best for the construction of door frames. Keeping wood in the mud is the best way to protect the wood for hundreds of years. Both *Divi-kaduru*/ Eve's apple (*Tabernaemontana dichotoma*) and *Goda-kaduru*/ strychnine tree (*Strychnos nux vomica*) stem, twigs, and leaves are good fertilizers to replace urea. Usually, *Kaduru*/Eve's apple or strychnine is grown along the bunds of the paddy fields, and it is pruned once four months, at field preparation.

Agarwood production is a protective mechanism within the plant against bacterial and fungal infections of genera *Aquilaria*, and *Gyrinops* (Subasinghe, and Hettiarachchi, 2015). *Aspergillus niger* and *Fusarium solani* are the most common fungal species found on Agarwood (Subasinghe, *et al.*, 2019b). Agarwood is produced inside the stem of Walla patta (*Gyrinops walla*), a low country wet zone endemic plant. It is chemically equivalent to the product of genera *Aquilaria* (Subasinghe, and Hettiarachchi, 2015). Harvesting agarwood is a rare chance in lowland forests (Fig. 6).

Important vines in wet zone forests

There are different vines in the forests used for different purposes. Among them, *Wewel* (*Calamus rotang*) is used for furniture making. There are six different types of *Wewel* namely *Heen wewel* (*Calamus pseudotenius*), *Mawewel* (*Calamus zeylanicus*), *Thambotuwel* (*Calamus ovoideus*) *Kukulu wewel* (*Calamus pachystemonus*), *Alawewel* (Scientific name is not confirmed), *Suduewel* (*Calamus ovoideus*) with specific properties for different products. *Bambara* vine [*Amerimnon championii* (Thwaites) Kuntze] is strong enough to hold in the mouth of elephants to help pull heavy logs or trees. *Wawuletiya* vine (*Caesalpinia hymenocarpa*) is used to bind the inflorescence of *Kithul* before tapping. *Kithul* pedicels are used to bind the bamboo structure of clay walls. *Weniwel* or *Banwel* (*Oscinium fenestratum*), a vine with high medicinal values is used to prepare the ladder for *Kithul* for tapping. This lasts around six months (Fig. 7).

Oils, wax, resins and toxic compounds from forest plants

Oils are extracted from different trees in the forest, namely *Dorana* (*Dipterocarpus glandulosus* Thwaites), *Kekuna* (*Aleurites moluccanus* (L.) Willd), *Mee* (*Madhuca longifolia*), *Madol* (*Garcinia hermonii*), *Domba* (*Calophyllum inophyllum*) and *Erandu* (*Jatropha curcas*). *Dorana* (*Dipterocarpus glandulosus* Thwaite) oils are used to apply over the paintings to protect the colour intensity of the paints and to get a glossy appearance. The statues in the temples have this shine due to *Dorana* oil. *Domba* oil is used to treat bone fractures in Ayurveda. Furthermore, *Mee*, *Erandu*, *Pus* (*Entada pusaetha*), and *Kumburu* (*Guilandina bonduc* L.) seed oils are used in Ayurveda. After milling oils, the residue is used to protect the hooves of farm animals from infectious diseases.

Kekuna tree exudates wax once the stem is damaged. A single cut is enough to collect 10-12 kg of wax and is used in oil lamps. This wax is dissolved in Kerosine oil and applied as a wood preservative. *Kekuna* wax mixed with *Dorana* oil is a durable paint for wooden furniture. *Yakahalu* (*Shorea oblongifolia* Thwaites), *Beraliya* (*Shorea oblongifolia*), *Mandora* (*Vatica paludosa*), and *Thiniya* (*Shorea trapezifolia*) trees produce *Dummala* (resins). Resins exude from the stems through the natural stem slits, and can be collected many times from the same slit. *Yakahalu* tree is endemic to Sri Lanka and is sometimes referred to as the *Dummala* tree.

Dummala was integrated into medication for pus-oozing wounds. Other than for medication, *dummala* was used for making flares in exorcism rituals. Besides that, *Dummala* is a perfumery material and a raw material for the production of varnishes, printing inks, coloring materials, adhesives and disinfectants. Using *dummala* for mosquito and gnat repellence is also evident (Subasinghe, *et al.*, 2019a). *Dummala* is burnt on the cracks of clay pots with latex from Jack to stop leakage permanently. Latex contains substances like alkaloids, terpenoids, and phenolics that impart anti-bacterial and anti-fungal characteristics (Murthy, 2021). The smoke of *Dummala* is made to fill in-house space in the evenings as a daily routine for reducing possible fungal growth and applied on the inside surface of the pots to attract honeybees. *Wil-Dummala* is the resins found in the deep earth that is used in a similar manner to wood *Dummala*. These are the carbonaceous coarse grain matters rich in magnesium carbonate, silica, and sulphur, but the carbon content



Katukenda (*Scolopia acuminata*)



Milla (*Vitex altissima*)



Mango (*Mangifera indica*)



Naa (*Mesua ferrea*)



Domba (*Calophyllum inophyllum* L.)



Dabu (*Syzygium gardneri*)



Ubberiya (*Carallia calycina*)



Hedawaka (*Chaetocarpus castanocarpus* (Roxb.) Thwaites)



Mahogany (*Swietenia mahaqoni* (L.)

Continue...



Burutha (*Chloroxylon swietenia*)



Uwa-Mandora (*Hopea cordifolia*)



Molpedda (*Isonandra compta*)



Bambarawel (*Dalbergia rostrata* Hassk.)*



Jak (*Artocarpus heterophyllus*)



Rukkaththana (*Alstonia spp*)*



Figure 6: Important wood species in wet zone forests of Sri Lanka. * indicates the plant species described under bee honey collection



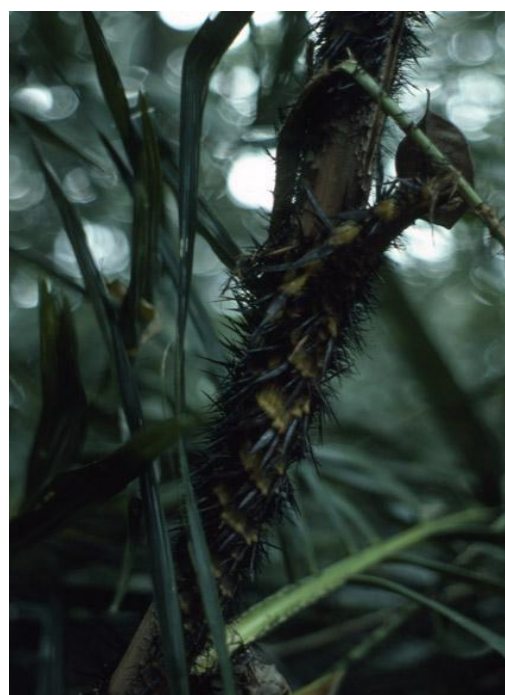
Wewel (*Calamus rotang*)



Heen-wewal (*Calamus pseudotenuis*)



Thambotuwel (*Calamus ovoideus*)



Ma-wewal (*Calamus zeylanicus*)



Kukuluwel (*Calamus pachystemonus*)

Figure 7: Important vine species in wet zone forests in Sri Lanka

in *Wil-Dummala* is yet to be analyzed (Subasinghe, *et al.*, 2019a). Diverse applications of natural resins have been extensively discussed (Avachat *et al* 2011). Resins from *Pinus brutia* were used by native people on the Kazdag Mountain in a similar manner (Satil *et al* 2011).

Kaduru/Eve's apple or *Strychnos nux-vomica* trees are pruned and added to paddy fields after harvesting for N supply and it suppressed the germination of weed seeds. Unrotten stems are collected and are kept on the bunds at the first land preparation and by the second land preparation, the stems are buried under the mud. During each planting season, the surrounding area of the paddy field is cleaned, burnt and the ash collected after burning is applied to the paddy field.

Cytotoxicity of *Kaduru* has been evaluated in terms of its medicinal properties (Perera, *et al.*, 1984; Ren, *et al.*, 2019), and cell apoptosis caused by four alkaloids extracted from *Kaduru* has been confirmed (Yin, *et al.*, 2017), but its potential usage as a nitrogen source or weedicide has never been tried.

Pandi (*Garra* sp), Hiitha messo, Magura (*Clarias* sp), Gam magura, Muudu penna, Dandi, Lellu, Thal kossa (*Belontia signata*), Kuunisso, Hora palaya, Bulath-hapaya (*Pethia nigrofasciata*, formerly *Puntius nigrofasciatus*), and eel (*Anguilla* sp) are the fishes found in the freshwater. All are edible other than small Bulath-hapaya. Kala-wel (*Dalbergia lanceolaria*) and Mii-anguna-wel (*Wattakaka volubilis*) are crushed and dipped in the water streams for fishing. Leaf and stem extract of Kala-wel and Mii-anguna -wel, make the fishes unconscious. Phyto-chemical properties of *Kala-welwel* have broadly been discussed in many scientific communications, and chemicals related to this purpose have not been reported yet (Fig. 8).

Leaves used for making mats and natural dyes from the local flora

Different leaves were used for weaving mats and containers by ancient people. *Indi* (*Phoenix farinifera* Roxb.), leaves are membranous and strong. Sun-dried *Indi* leaves are used to prepare mats and hats. *Magala* is a 6 m long mat woven with four-layered coconut leaf-strips. *Haven* (*Cyperus pangorei*), *Gal-eh* (*Cyperus corymbosus*), *Minuwan* (Scientific name is not available), and *Thunhiriya* (*Schoenoplectus grossus*) are also different types of sedges used to prepare mats and containers for domestic purposes. Large sacs woven with coconut leaves were used to store rice seeds on the mantel.

Hevan, *Gal-eha*, *Thunhiriya*, *Minuwan*, and *Pothukola* (*Scleria poaeformis*) mats were used for

sleeping. *Pothukola* mats are specially prepared for new-born infants and good for muscle development. Wood-ash is applied over the leaves before sun-drying to prevent pest attacks. Rubbing leaves with a wooden stick is needed to polish the leaves for easy handling. *Minuwan*, *Hevan* or *Thunhiriya* must be split into three before weaving. The longer and broader leaf type *Dunukeyya* (*Pandanus thwaitesii*), *Wetakeyya* (*Pandanus kaida*), *Wiyakeyya* (Scientific name is not available), and *Okeiya* (*Pandanus ceylanicus*) are boiled before drying for weaving mats. *Okeiya* grows profusely along the riverbanks.

Katu-kithul (*Oncosperma fasciculatum*), found only in Sri Lanka has a large spathe at the base of the leaf. It is very strong and lasts comparatively a longer time than the spathe of other palms. Ancient people used *Katu-kithul* spathe for making buckets and plates.

Natural dyes were used on different materials by ancient villagers. The sedges were coloured by boiling with the hardwood of Pathagi (*Caesalpinia sappan*) for weaving mats, hats, and containers. Pathagi is red in colour and Wal-rabutan (Scientific name is not confirmed) fruits are mixed with Pathagi to produce bright red colour. The coloring of Monk's robes is done by boiling with dried *Bombu/sapphire-berry* (*Symplocos cochinchinensis*) leaves and turmeric (*Curcuma longa*). *Kuda-gal* (partially weathered parental material), *Sudu-gal* (dolomite), *Kahannda* (S-containing stones), and *Guru -gal* (plinthite, hematite, or laterite) are used for painting walls and statues in temples, and *Dorana* (*Dipterocarpus glandulosus*) oil is applied over the paints for fixing and preserving the colors with a shiny finish (Fig. 9).

Animal rearing and honeybee collection

Rearing buffaloes is a part of the life of the villagers for milk production, ploughing paddy fields and threshing rice. After field preparation in April for *Yala* season, cows are brought to the forests, and fences are fixed to keep the buffaloes inside the natural paddock. The fence is not a complete circle, but long enough to close the footpaths that people use to cross the land. The fence demarcates the grassing area for the buffaloes until the owner comes to bring them back to the village after months. Threading a *Madu/ Hog vine* [*Camonea bifida* (Vahl) Raf.] around the two horns of the leader buffalo is a traditional method to seek the protection of the herd from *Diviya/Rusty-spotted cat* (*Prionailurus viverrinus*) or tiger (*Panthera tigris*). After harvesting



Kekuna (*Aleurites moluccanus* (L.) Willd)



Yakahalu (*Shorea oblongifolia* Thwaites)



Mandoran (*Vatica paludosa*)



Thiniya (*Shorea trapezifolia*)



Kaduru (*Strychnos nux-vomica*)



Kalawel (*Dalbergia lanceolaria*)



Domba (*Calophyllum inophyllum*)



Erandu (*Jatropha curcas*)



Mee (*Madhuca longifolia*)

Continue...



Pus (*Puseta Entada pusaetha*)



Madol (*Garcinia hermonii*)



Beraliya (*Shorea megistophylla*),



Kumburu (*Guilandina bonduc L.*)



Kotikan-Beraliya
(*Shorea cordifolia*)

Figure 8: Plants used for collecting wax, resins, toxins, and oils in wet zone forests



Indi (*Phoenix pusilla* Gaertn.)



Dunukeyya (*Benstonea thwaitesii* (Martelli) Callm. & Buerki)



Watakeyya (*Pandanus candelabrum*)



Pathagi (*Caesalpinia sappan*)



Bombu/sapphire-berry (*Symplocos cochinchinensis*)



Pothukola (*Scleria poiformis* Retz)



Gal-eha (*Cyperus corymbosus* Rottb)

Figure 9: Leaves used for making mats and plant species used to produce natural dies

rice, buffaloes are brought back to the village in August for threshing rice and they feed on the leftover from harvested rice plants (*Ipanella*) until the land preparation in November for the *Maha* season. Hunting pigs (*Sus Scrofa domesticus*), Gona/ the Sri Lankan Sambar deer (*Rusa unicolor unicolor*), and porcupines (*Hystrix indica* Kerr), are common for two reasons: consumption and protecting cultivation. However, Sri Lanka Sambar deer is considered an innocent animal, and their hunting is discouraged. Locally mounted guns by blacksmiths are used for hunting and trapping animals is also a common method.

Bee-honey (*Apis cerana*) collection is one of the most important tasks in forest visits. Beehives can often be found in stone hedges and knotholes in the forest. If bees move their wings fast, and bees appear yellow in color, such hives are filled with bee honey. If the bees appear black at the spout of the knothole, such hives don't have beehoney. Decaying *Kithul* stems are occupied by honeybees, and many hives can occur in such places. About 20 L of bee honey can be harvested from a decaying *Kithul* trunk with several beehives.

Usually, pollens from all the flowers are collected by bees, but pollen from the *Babara* (*Amerimnon championii* Thwaites Kuntze) imparts a bitter taste to the honey. *Rukkaththana* (*Alstonia kurzii* Hook.f.) pollen is poisonous for *Debara*/ the lesser banded hornet (*Vespa affinis*), *Babara*/Giant honey bee and honey bees (*Apis cerana*) and they die after collecting the pollen from *Rukkaththana* flowers. *Babara*/Giant honey bee (*Apis dorsata*) honey is also edible, but it's watery. During *Rukkaththana* (*Alstonia kurzii* Hook.f.) flowering season, reptiles don't wander in those areas. There are no reports on phytochemicals imparting this toxicity in *Rukkaththana* on bees or reptiles, and it is something yet to be analyzed. (Fig. 10)

Villagers harvest bee honey when the rain starts after January and November dry months. Rice grown in the *Maha* season starts flowering in January and beehives are filled with bee honey in January. Rice grown in *Yala* season starts flowering in July and bee honey can be collected in August. Further, Mango and other fruit trees start flowering in November and December, and these months are favorable for harvesting bee honey. Wax in hives of bees and hives of the giant honey bees is used for treating abscesses with resins found in earth (*Wil-dummala*) and in *Vateria copallifera* (*Hal-dummala*).

Non-timber products of lowland forest resources must be utilized for sustainable development. Interdisciplinary research studies are required to

optimize sustainable production systems related to non-timber products in Sri Lanka (Gunatilleke, and Gunatilleke, 1993).

Conclusion

A considerable effort is needed to domesticate or commercialize edible mushrooms in lowland tropical forests. *Olu-weli-hathu*, *Heen-weli-hathu*, *Maa-weli-hathu*, *Indalolu-hathu*, *Muukalan-hathu*, and *Ooru-hathu* are edible tropical mushrooms. Understanding the climatic and soil factors affecting their phenology will be fundamental for domesticating these highly productive and fast-growing mushrooms compared to temperate mushroom species. The miracle of the kingdom of fungi, *Kanamediri-hathu* (*Mycena*), that shines at night has not been utilized for any purpose so far in Sri Lanka. *In-situ* conservation of such resources will further facilitate eco-tourism. In addition to local mushrooms, aquatic edible leaves, wild fruits, and nuts have a great potential for commercialization as functional foods targeting local and international markets. Research directed at overcoming seasonality for year-round production methods is needed for the success of such ventures. Awareness of the society on the possible uses of different native timber species and the development of their cultivation methods will be important for their conservation, optimizing their use, and minimizing energy footprint on the earth. Studies must be focused on the natural substances; oils, wax, resins, and toxic compounds of leaf extracts with diverse characteristics for mass-scale production and uses since all are biodegradable and do no harm to the existing diversity of flora and fauna. The insecticidal, antibacterial, antifungal, and phytotoxic properties of these materials should be evaluated, and methods developed for the extraction of the active compounds for integrating them with agricultural, pharmaceutical, nutraceutical, cosmeceutical, and ethnobotanical purposes.

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Thel-karawala (*Bungarus ceylonicus*)



Mal-karawala (*Rhabdophis ceylonensis*)



Maapila (*Boiga ceylonensis*)



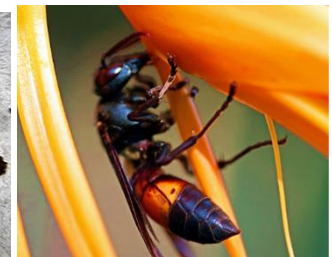
Thal kossa (*Belontia signata*)



Bulath hapaya (*Pethia nigrofasciata*)



Magura (*Clarias brachysoma*)



Vespa affinis



Pig (*Sus scrofa domestica*)



Gona (*Rusa unicolor*)



Porcupine (*Hystrix indica*)



Bombus terrestris

Figure 10: Reptiles, fishes, and animals described in wet zone forests in Sri Lanka

The pictures of the figures were copied from online sources. The author would like to acknowledge the photographers of the original pictures.

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