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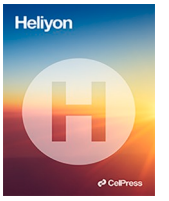

Accumulate and consolidate the traditional vernacular timber preservation technologies through a field survey

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ABSTRACT

There are remarks on diverse types of timber structures in the tropics. This paper examines several case histories in Sri Lanka, focusing on the culturally varied and ecologically diverse traditional buildings with wood used for construction. The main objective was to gather data and document the knowledge on wood preservation. Information was gathered through face-to-face interviews with 270 individuals' reference to 138 structures. A holistic analysis was performed to understand the techniques used to overcome the degradation mechanisms and state of conservation. The demographic profile of the informants was evaluated and cross-relationships on the tabulated data were analyzed by SPSS statistical software following the snow-balling sampling technique. There were three main preservation techniques identified from the open-ended questions namely, wood kept under smoke pits, wood kept under paddy field mud, and wood kept under the river banks. Preserving wood by keeping it under paddy field mud (49.62 %) was the highest recorded answer. The most obtained material matrix of preservation was plant origins (48.88 %). For generations, people have transmitted traditional and cultural practices through oral knowledge. The results conclude this knowledge places a high value on protecting construction technologies and applications while preserving biodiversity. Unfortunately, by today this technology has started extinct. The results revealed the importance of social norms and cultural perceptions as a set of valuable information that was practiced with a great history in a tropical country.

1. Introduction

Urbanization leads to a rapid increase in for demand goods and services. This has started influencing the economy and the environment of a country [1,2]. This erected the world of construction to build sustainable solutions in applications but relatively, to alter the way of thinking into understanding and handling economic, environmental, and cultural values. Today, the construction industry has become a significant contributor to the environment all over the world [3]. Building activity is increasingly pitched

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toward designing and using sustainable construction materials, production, and management processes based on biocompatibility, energy-saving, and the economy. Along with that there is growing acceptance of resource management, a vital role that forest resources and timber resources ought to be managed to meet the social, economic, ecological, and cultural needs of present and future generations and minimize raw material depletion [4–8]. As a result of this people started developing techniques to improve the service life of the materials. The pathway to sustainable development requires an eco-efficiency step. This step of reducing impacts and costs during the entire life-cycle of the built assets are parallel change options to new approaches [9]. Environmental concerns, such as water quality standards, air, the effect of treated wood on humans and other organisms, and the energy crisis, particularly when it comes to oil-based preservative systems, were the main factors driving variations in treatment technology and conservation systems around the world [10].

In many external uses, wood is a renewable natural resource that is often treated with a preservative to guarantee structural integrity. Due to biological attack, wood species that did not have intrinsic decay resistance traits failed in service, necessitating the use of preservative-treated wood. Toxic chemicals are commonly used to preserve wood against insects and deterioration. These can be hazardous to the environment and toxic to a variety of animals and plants, especially aquatic life such as fish, aquatic insects, and aquatic plants. With these raising questions, the public is now seeking preservatives with a high degree of efficacy against the wood deteriorating agents, as well as expects safety in handling and during service.

Newer process methods show promise for new wood preservatives and lead toward modern developments in commercial production plants and research prospects. Consumer education about new wood-treating chemicals and products is becoming more important [11]. There is a significant requirement of understanding the characteristics of construction materials like wood from the macro to ultra-structure towards the wood-engineering and global policies that could maximize forestry and timber construction as a benefit to people and the planet [12]. With this significant global attention, there are sources still existing in the tropics -where the wood lasts for years from the specific treatments that comprise unrevealed technologies [13–16]. Ancient cities of a country are unique for their geographical diversity, and their form and function [17,18]. Where these represent a symbiosis between nature and culture. The study emphasizes the requirement of revealing the existed knowledge and preserving them for future applications.

The need for cultural protection has just recently become apparent, even though the need for biodiversity protection has long been recognized [19]. Understanding their interplay and interaction is critical to guaranteeing the survival and flourishing of both nature and culture. Nature and culture merge in many ways. From values, beliefs, and nomenclatures to practices, ways of life, knowledge, technologies, and languages [20,21]. As a result, cultural systems and the environment have mutual feedback, with changes in one frequently affecting changes in the other. Culture can be defined as the methods via which people perceive their surroundings [22]. The meanings and interpretations have a wide range of connections to the natural environment, with the most obvious connections occurring most frequently in traditional resource-dependent communities. Socially in-built norms and rules are also influenced by ecological knowledge [23]. These normalize human interactions and behavior about the natural environment, and they have frequently co-evolved to ensure the survival of both people and nature [24]. These rules determine access rights acceptable behavior and the productivity and diversity of socio-ecological systems, which is ultimately in the community's best interests [25]. As a result of cultural extinctions induced by assimilation, language loss, and knowledge loss, these factors are also paving the way for greater cultural monocultures. Traditional livelihoods are being replaced by contemporary occupations, and rural groups are relocating to metropolitan regions at the expense of cultural variety. Oral knowledge is being replaced by written knowledge, and traditional livelihoods are being replaced by modern occupations [26]. This comes at a cost to human society, as a decrease in knowledge reduces humanity's potential answers to future global crises.

Culture is enclosed by nature. To use a metaphor, nature is the womb of culture, yet it is a womb that humans never really leave [11]. Nature can accomplish a great deal without the aid of culture, as seen by billions of years of evolutionary history. Culture, which emerged late in natural history, cannot function without nature's support. In this sense, culture will always have to be built from nature and superimposed on it. Significant timber constructions still exist by overcoming wood deteriorating agents in a tropical country like Sri Lanka [27]. It was observed, that these structures had used precise timber processing techniques to overcome the mechanical failures revealing proper material manipulation [28]. With regard, this raises a question on how did they overcome the challenges against other main wood deteriorating agents like termite, fungi, fire, marine borers, etc. Therefore, this study attempts to accumulate and consolidate the traditional vernacular timber preservation technologies by investigating the ancient timber structures in Sri Lanka. The main aim of this paper is to gather data and document the knowledge on traditional wood preservation and then provide a preliminary discussion of the requirement of knowledge relevant to nature and the cultural symbiosis in the contemporary wood industry. Also, to emphasize the community and the construction role that existed where this knowledge could play in delivering this global need.

2. Materials and methodology

The main sources of ancient timber architecture in Sri Lanka are the remains of religious edifices of Buddhist and Hindu Shrines at the current contest [29]. There are three sources from which can date the architectural remains of Sri Lanka. The "*Mahawansa*"; (a massive chronicle that details each King's accomplishments during his reign), Epigraphical evidence; (Often used to mark a donation of a building or a monastery, these letters are inscribed on rock), and Archeological Evidence; (Evidence from excavation, and are physically seen).

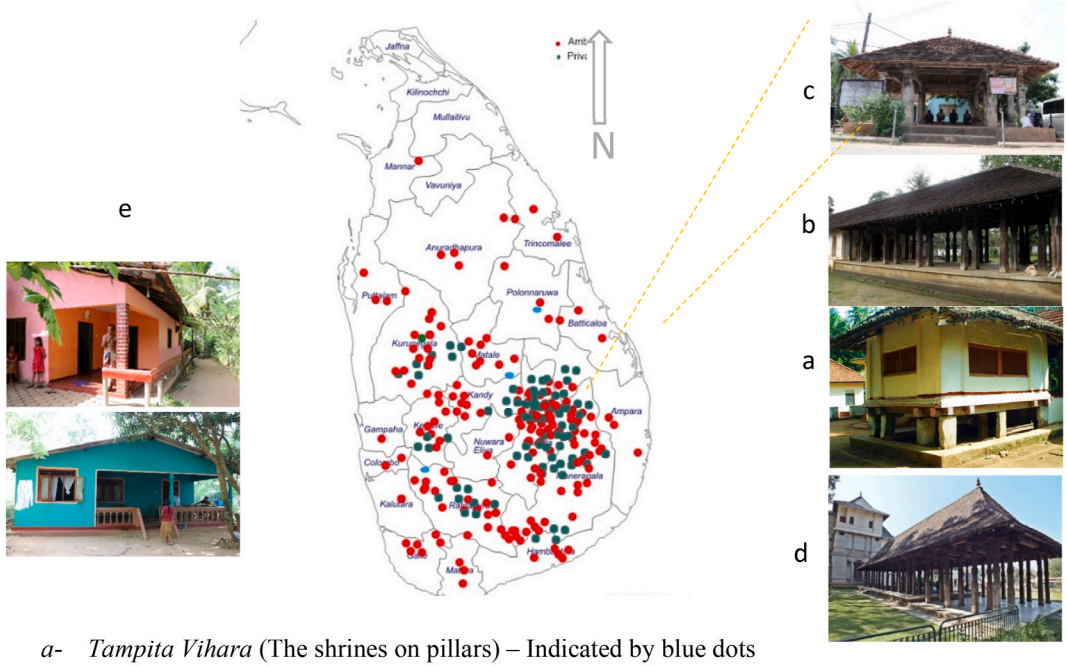
2.1. The selected cases

Among the three, the physical structures visualizing the construction topography were selected for this study. Fig. 1 denotes the locations of the identified cases using colored dots.

The structures placed above the ground on pillars(a). The structures dedicated to gods or deities are known to be *Devala* (b). An Ambalam(s) is an open colonnaded, hip-roofed space, introduced as a building type that originates under traditional vernacular architecture in Sri Lanka(c) [17]. These structures were allocated to charitable services commenced by the villages under the patronage of the village head or the chieftains. Ambalam(s) also conferred the travelers as a landmark to accomplish the journey and a public gathering place for the villages. The structures are constructed as assembly places for administrative routines(d) [28,29]. Further, the study identifies cases that are private residents; hip-roofed spaces as shelters originating under the traditional vernacular architecture in Sri Lanka(e). During the pre-screening, it was identified that no Architects or Engineers were involved in the construction unless ordinary skilled people constructed them [18].

2.2. Sampling technique and the field survey

Initially, the locations were identified through sources from the Archeological departments and a comprehensive literature review. The other locations were identified through the information gathered through the primary locations. The initial sample size was 116 and was expanded to 138 by using the snowball sampling technique. An island-wide field study was initiated as the first step in decoding and documenting the existed knowledge practiced by Sri Lankans' on treating timber to overcome the challenges in tropical climatic contexts. Information was collected through face-to-face interviews; with 270 individuals in 138 selected cases (minimum 1 individual per case). Information was solicited in close-ended and open-ended questions. As described in Fig. 2, the demographic features of 270 individuals were determined. The participants were asked about the building description and the preservation technique practiced through this questionnaire. They consciously avoided soliciting information on particular structures to prevent bias in the data collection. The interviews were generally conducted as follows: Fifteen numbers of the archeological regional offices and literature were contacted and referred to identify the most justifying cases. Then visited the participants near the identified cases and asked them to gather neighbors who are particularly familiar with the use of preservation techniques. Some interviews were also carried out in village gathering centers, where men spend their leisure time. In each case, the interviewers were allowed to discuss the use of any preservatives or the materials used thoroughly among each other.



a- *Tampita Vihara* (The shrines on pillars) – Indicated by blue dots
b- *Devala* (Shrines dedicated to deities) - Indicated by blue dots
c- *Ambalam* (Resting places for travelers) – Indicated by red dots
d- *Mandapa* (Assembly places for administrative routines) (Indicated by blue dots)
e- Private residences (constructed using traditional vernacular construction typographies)

Fig. 1. Locations of the identified cases; Red dots denotes the Ambalam Structures, and the green dots denotes the private residences. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

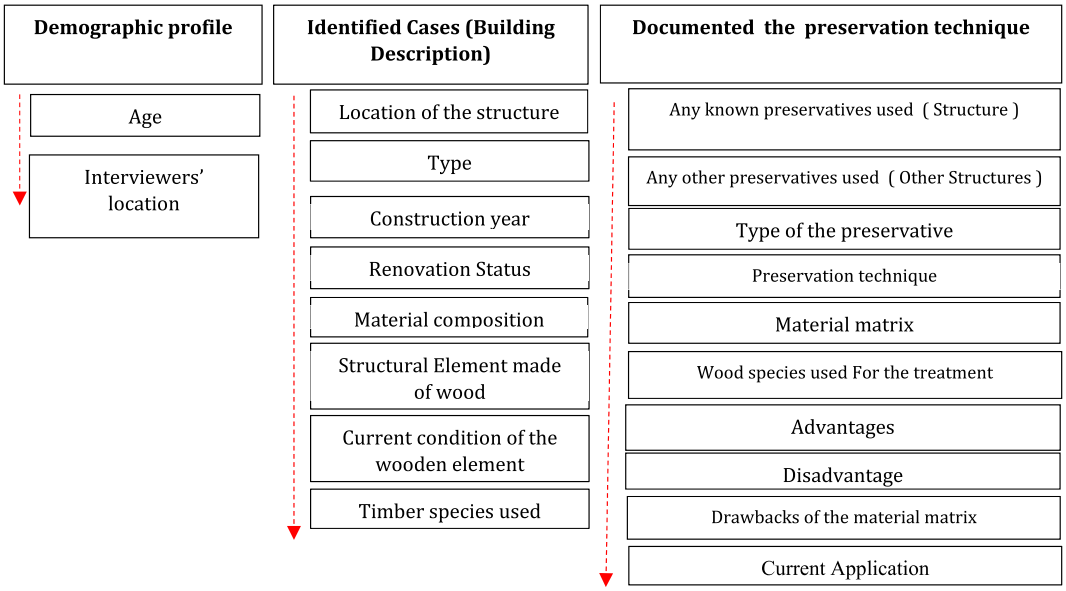


Fig. 2. Flow chart of the detail's phases of the survey.

The survey is based on three phases the demographic profile of the interviewer, the building description, and the documented facts on timber preservation technique; As mentioned in above Fig. 2.

2.3. Statistical analysis

Results were evaluated statistically using SPSS 23 (Statistic Pockets for Social Science) statistical software: The chi-square test was used to compare different groups of data. (The specific demographic features of the participants related to the preservative technique and the material matrix. were cross-analyzed.

3. Results and discussion

The results were analyzed as below.

3.1. Demographic profile

The demographic profile of the participants is summarized in Table 1. It was observed, that the majority of the participants were males in gathering data representing 62 0.0 % of the total. The 42.0 % majority of the interviewers were in the range of 60–79 years.

3.2. Identified characteristics of the structures (building description)

The awareness of identified cases among the participants is summarized in Table 2.

There were main building categories identified in the survey, Archeological monuments representing *Ambalam(s)* *"Dewala", "Mandapa", "Tampita",* and the old private residences. Among them, 63.9 % majority represented *Ambalam(s)* and then the Private Residents 20.7 %.

Table 1
The demographic profile of the survey (n = 270).

Characteristic	Test variables	Frequency	Percentage
	21–39 years	4	1.3 %
	40–59 years	112	36.7 %
	60–79 years	128	42.0 %
	80 years above	26	8.5 %
The place where the interviewer lives	I am a villager	210	68.9 %
	I am from a nearby village	8	2.6 %
	I am new to this village	4	1.3 %
	I am an outsider	7	2.3 %
	I am a field officer from the Department of Archeology	41	13.4 %

Table 2
building description.

Characteristic		Frequency	Percentage
Provinces	Central Province	57	18.7 %
	Eastern Province	2	.7 %
	Northern Province	2	.7 %
	Southern Province	28	9.2 %
	Western Province	37	12.1 %
	North Western Province	50	16.4 %
	North Central Province	10	3.3 %
	Uva Province	48	15.7 %
	Sabaragamuwa Province	36	11.8 %
Districts	Badulla	48	15.7 %
	Anuradhapura	10	3.3 %
	Ampara District	2	0.7 %
	Colombo	7	2.3 %
	Galle	10	3.3 %
	Gampaha	30	9.8 %
	Hambantota	3	1.0 %
	Jaffna	4	1.3 %
	Kaltura	2	0.7 %
	Kandy	38	12.5 %
	Kegalle	33	10.8 %
	Kurunegala	46	15.1 %
	Matale	19	6.2 %
	Matara	15	4.9 %
	Rathnapura	3	1.0 %
Building type	*Ambalam(s) (A wayside resting place)*	195	63.9 %
	Dewala	3	1.0 %
	Mandapa	2	0.7 %
	Tampita	7	2.3 %
	Private Residents/house	63	20.7 %
The material composition	Completely timber	66	21.6 %
	Brick and mortar and timber	167	54.8 %
	Stone and timber	32	10.5 %
	Stone, brick, and timber	5	1.6 %%
	Completely timber	66	21.6 %
The age of the building			
	21–30 years	2	0.7 %
	31–40 years	60	19.7 %
	41–50 years	1	0.3 %
	>50 years	207	67.9 %
The timber species	Known	8	2.6 %
	Not known	175	57.4 %
	Not sure	25	8.2 %
	to some extent	62	20.3 %
	Known	8	2.6 %
The current status of the building	Healthy	222	72.8 %
	Visibly damaged	4	1.3 %
	Started deteriorating	43	14.1 %

The results were as follows.

Among the identified buildings 67.9 % were more than 50 years old. All the identified 195 Ambalam(s) structures were over 50 years or more than 100 years in age, while the identified 63 private residencies were in the age range of 20–50 years old; (Graph 1 and Graph 2).

The *"Dewala", "Mandapa", "Tampita"* are considered sacred places in Sri Lankan culture and, according to historical records, these structures were built for special religious reasons. But the sample number of these structures is less relative to *Ambalam* and old private residences. Here the study focuses on the cases with minimum religious impacts focusing more on shelter used by the ordinary people. Therefore, *Ambalam* (63.9 %) and private residences (20.7 %) are identified as the most justifying cases. It was concluded the timber species used for the construction of Ambalam was not revealed. While the majority of the private residences' timber species used for construction were known to certain extent (Graph 3 *and* Graph 4*)*; Revealed as Mango, Hora, Milla, etc

3.3. Awareness of the preservation technologies of the identified structures

The questions were asked to identify how far the preservation technologies go back with time. Further questions were asked to

grasp the information about recent renovations done on the structures and to see through the possibility of revealing any preservation techniques used. Table 3 depicts the frequency and the percentage of the answers.

More than 90 % of respondents' answers were presented as there were no surface applications used to any of those structures recently or in a period that they can recall. Chi-square tests were done (Table 4) to understand whether there is a significant difference between the age of the building and the awareness of the wood preservation techniques used.

According to the results, there is a significant difference between the age of the building and the awareness of the wood preservation techniques used on the identified structures. Participants had lack of awareness about the methods or technologies used to preserve the wood of the cases represented over 50 years in age but, they were actively responding about the preservation techniques of the structures constructed below 50 years. The majority of the *Ambalam(s)* were constructed more than 100 years ago (Graph 5 and Graph 6), When the age is more than 50 years the preservation technique and the utilized wood species were not known. Therefore, the research was then narrowed down to old private residences for further analysis, which were constructed 20–50 years ago (see Fig. 12).

3.4. Identification of traditional vernacular timber preservation technologies

The questions were asked to identify the main characteristics of timber preservation technologies that were inherited for an average of 30–50 years. Since inadequate knowledge was obtained from literature relevant to ancient timber preservation techniques open-ended questions were asked about known preservation techniques and the materials or chemicals used which weren't documented clearly in any historical records. Table 5 briefs the information gathered from the participants. According to the results, there were organic and inorganic methods used. Among them, organic methods seemed to be popular (57.03 %). There were three main preservation techniques identified from the open-ended questions namely, wood kept under smoke pits; (Large piths were prepared, then the wood logs or the sawn timber was placed inside and then sealed from to latter the smoke is sent to the pith), wood kept under paddy field mud; (Large piths were prepared in paddy fields, then the wood logs or the sawn timber is placed inside and submerged in paddy field mud), and wood kept under the river banks (Wooden logs fixed with ropes to the river banks submerged in. The most recorded answer was preserving wood by keeping it under paddy field mud (49.62 %). The most recorded material matrix of preservations were plant origins (48.88 %) and 80.65 % of the respondents knew the type of wood chosen to preserve to a certain extent, using particular preservation techniques. Hence the authors recommend further investigations should be conducted for timber identification to reveal the used timber species under the said preservation technique.

The following characteristics are expected in developing an ideal wood preservative (Fig. 3).

The preservative's fatal toxicity against fungus, insects, and marine borers should be significant even at low concentrations, with a low degree of lethal effects for mammals [18]. There should be no or minimal adverse effects on people during usage and handling. The preservative should be reasonably priced and easily available. And the ability to easily transport over great distances. The preservatives should not have an unfavorable effect on the wood's strength or other properties. The chemical preservatives used can be dissolved in either water or oil. In any event, must not be overly combustible or non-targeted organisms. Also, must be cost-effective concerning economically beneficial to use [29–31]. High responsiveness, allowing it to infiltrate the treated wood's whole cross-section for a longer-lasting effect. Among all, the toxicity of the solution against fungus, and insects, was questioned.

Then a 1–5 Likert scale question was asked to identify the experience or beliefs they had on the certain characteristics of wood preservatives accordingly. The 1 on the scale was for strongly disagree (SD), and 5 for strongly agree (SA). The 3 in the scale was used for the neutral (N) opinions. The characteristics of the wood preservatives were cross-tabulated with the responses of agreeing and strongly disagreeing with the known preservative techniques (Table 6).

The characteristics of the wood preservatives were cross-tabulated with the responses of agreeing and strongly agreeing with the known preservative techniques. According to the responses wood kept under paddy fields' mud showed more than 90 % of the preservative characteristics. According to the overall analysis of the identification of traditional vernacular timber preservation technologies, woods keeping under paddy field mud was the most known method of the interviewers and it seemed to successfully come through many generations. The further analysis was directly focused on the said preservation technology to identify plant species for further development.

Table 3
Awareness of the preservation technique.

Characteristic	Test Variable	Frequency	Percentage
Any Surface applicants used for the structure recently/known period	Yes	0	0
	Known to some extent	0	0
	Neutral	26	9.63
	No	244	90.37
Awareness of the wood preservation technique used to treat the wood used in the structure	Yes	45	16.67
	Neutral	20	7.40
	Not sure/maybe yes	46	17.03
	No	159	58.89
Awareness of preservation techniques used in any other structure	Yes	78	28.89
	Known to some extent	76	28.14
	Neutral	0	0
	No	116	42.97

Table 4
Chi-Square test (α = 0.05).

Test Variable	Awareness of the wood preservation techniques used to treat the wood of the identified structure	Awareness of preservation techniques used in any other structure
Age of the building	p = 0.000	p = 0.003

Table 5
Characteristics of the known vernacular timber preservation technologies.

Characteristic	Test Variable	Frequency	Percentage
The type of known preservative	Organic	154	57.03
	Inorganic	90	33.33
	Don't know	26	9.64
Known Preservation techniques	wood kept under smoke pits	8	2.96
	wood kept under paddy field mud	134	49.62
	wood kept under the river banks	12	4.44
	Don't know	116	42.96
The Material Matrix	plant origins	132	48.88
	Animal origins	8	2.96
	mineral extracts	91	33.70
	artificial chemicals	2	0.74
	Don't know	37	13.70
The type of wood used	Know	45	16.67
	Don't know	52	19.25
	Not sure/Maybe	132	48.8
	Known to some extent yes	41	15.18

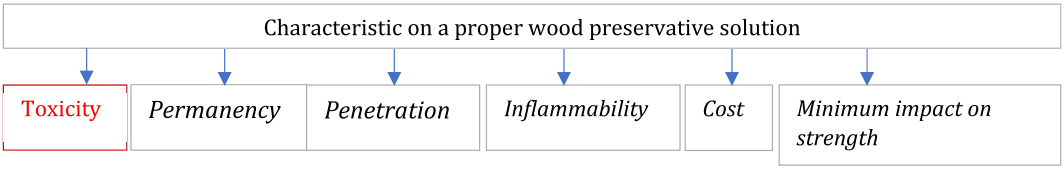


Fig. 3. Flow chart of the characteristics of the preservation solution.

A ranking question was presented to identify the reasons for avoiding wood preservation by keeping it under paddy field mud (Table 7).

According to the ranking results, the main reason was the difficulty of the preservation process for the villagers to undertake on some scale, and the second most identified reason was the requirement of having paddy fields. Most of the villagers did not own their paddy fields and even if they had they were reluctant to undertake these processes since they have easy modern methods. Most of the respondents' stated that the process causes heavy odor (ranks 3) and it makes them and their neighbourhoods' uncomfortable.

3.5. Transformation of the timber preservation technologies through generations

The open-ended questions were presented to analyze the vernacular history of wood preservation technology. The questions were focused on, where they first heard of the technology, where they learned further about the technology, have they experienced the methods, and have they or any person of their relations had done the modifications or retentions to the technology.

The figure 4 below represents the observed knowledge transferring map of preservation technologies in the generations.

The gathered information was further analyzed as follows. When the answer was "No" to the question "Did you further improve the said process". The questions were asked to determine what technique was more effective under the interview's perception. The wood is kept under paddy field mud or the wood is kept under the paddy field mud developed using the plant parts.

The highly recoded answer was the wood kept under the mud developed using plants presenting 64.67 %. The questions were then asked to identify the awareness of any improvement done to develop the known timber process. The results disclosed that 15.9 % of participants revealed on techniques used to develop the wood kept under the paddy field mud. Among them, 15.6 % of participants revealed an improvement done by adding oils, and 48.3 % of participants revealed an improvement done by adding plant parts. The majority of the decoded improvement by adding plant species were further analyzed as follows.

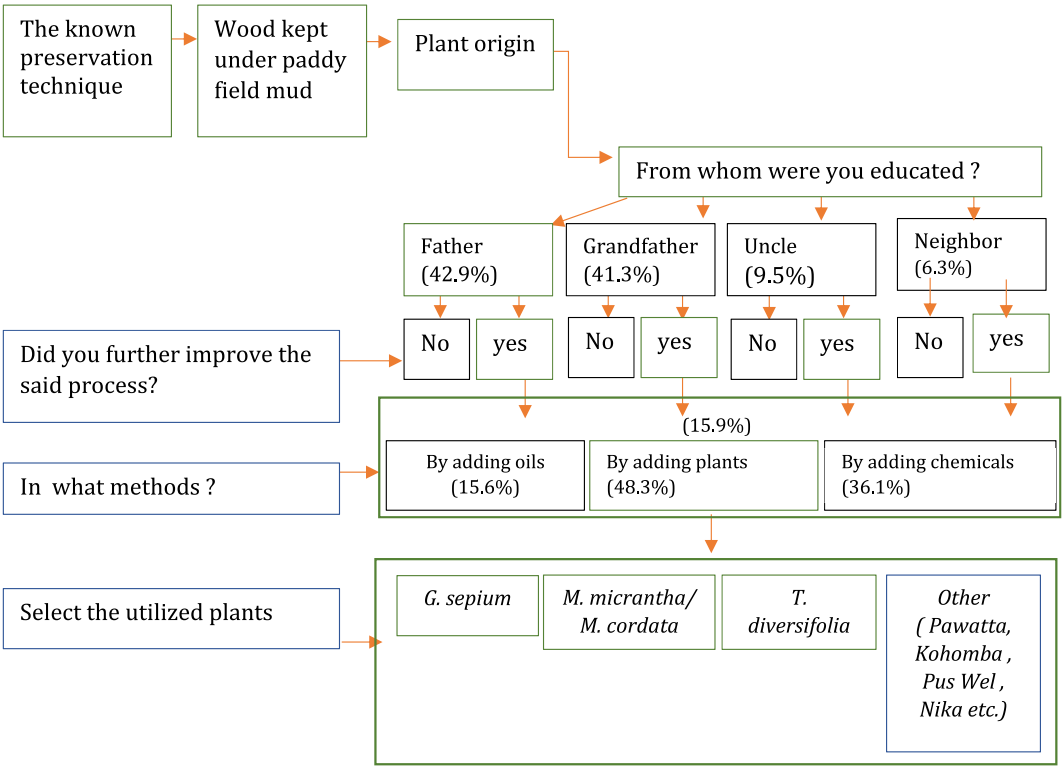


Fig. 4. Graphical representation of knowledge transferred by generations of the Wood kept under paddy field mud.

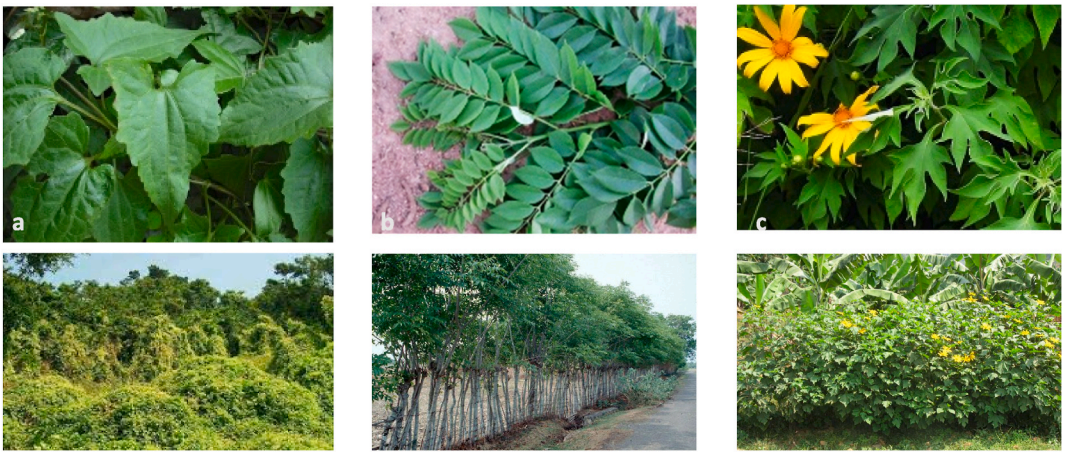
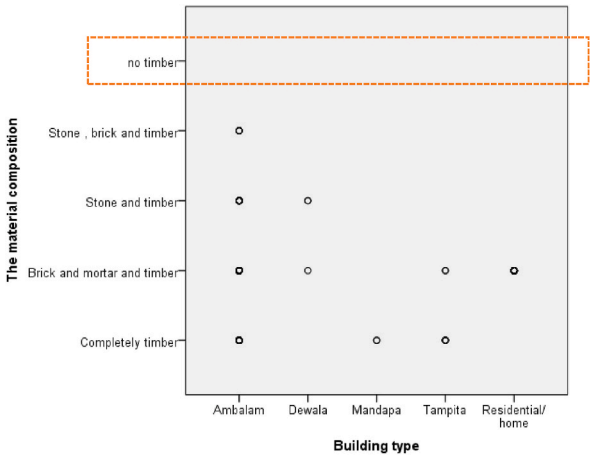


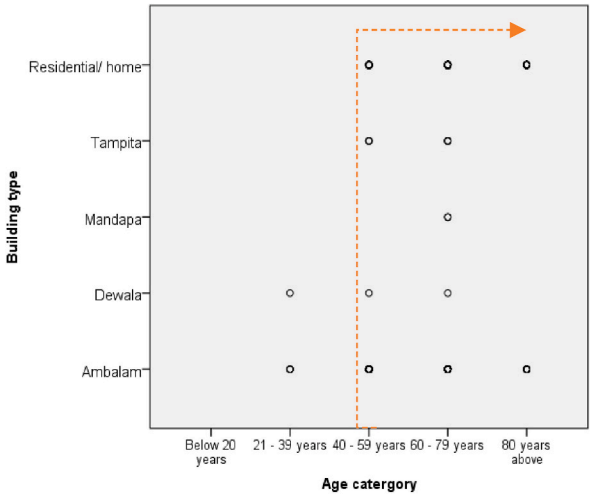
Fig. 5. a-Mikania micrantha, b- Gliricidia sepium, c- Tithonia diversifolia.

3.6. Awareness of the plants species used to develop the paddy field mud

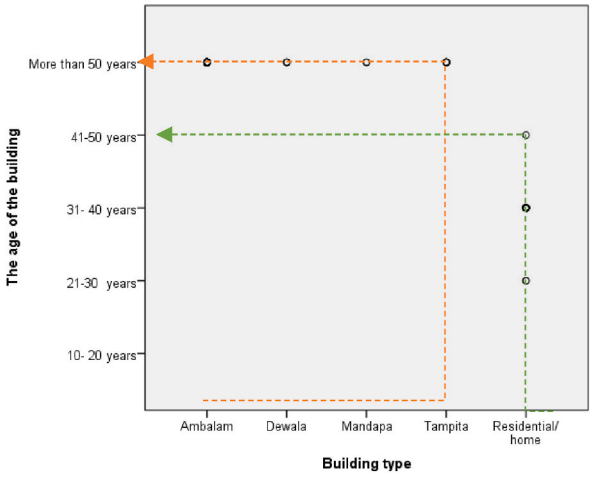
The open-ended questions were asked for known plant species used to develop the mud before the wood was kept under the paddy field mud (see Fig. 4). According to the results, few plant species seemed to be popular among them. The survey revealed around 10 to 12 plant species that have been used with the documented preserving practice. Plants such as *Adhatoda vasica, Croton aromaticus, Azadirachta indica, Gliricidia sepium, Mikania micrantha, Tithonia diversifolia, Mikania cordata … etc most of them are exotic plant species.* Among all, the results revealed majority used three types of plant species in common, (Chart 1, Chart 2, Chart 3). Further literature revealed the nutritional value, fast-growth/growth performance, and high regeneration capacity with high potential for forage productions might be the major reason for documenting the *Gliricidia sepium* [32,33], *Mikania micrantha* [34,35], *Tithonia diversifolia* [36, 37] in developing the treatments (Fig. 5).



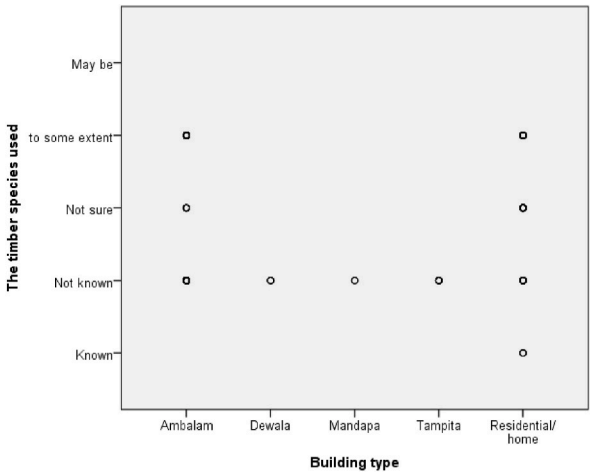
Graph 1. Building type Vs The material composition.



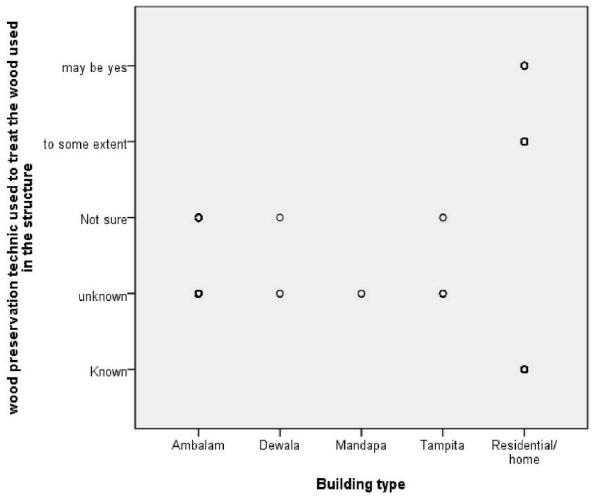
Graph 2. Age category of the interviewer vs building type.



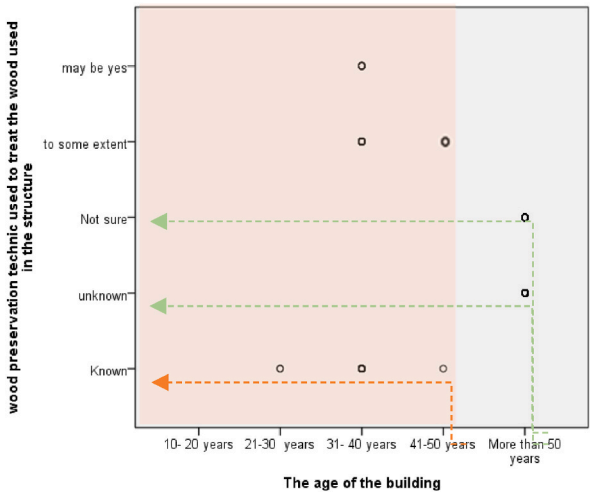
Graph 3. The building type Vs The age of the building.



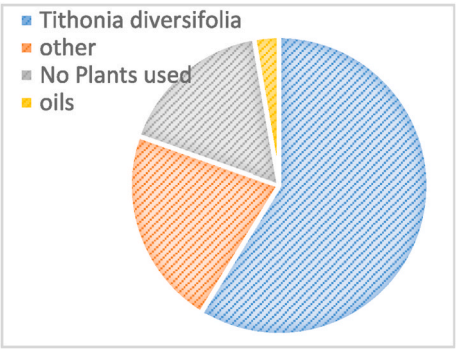
Graph 4. The building type Vs The timber species used.



Graph 5. Building Type and the preservation technique used to treat the wood with in the structure.



Graph 6. The age of the building and the preservation technique used to treat the wood used with in the structure.



Graph 7. Wood preservation vs current usage of the decoded traditional vernacular technology.

The questions were then asked to determine the current application of the documented traditional vernacular preservation techniques. The results disclosed that 87.2 % represented not using any of the traditional vernacular preservations under current practice.

3.7. Identify potentials to formulate a preservative solution

The field survey revealed a technique practiced as follows; the quality of paddy field mud was developed using the plant species found close by and then placing the timber under mud until it was used. Further, the study has accumulated a few wood species (Table 8) which were dominantly discovered by the interviewers as timber species used for construction by the ancestors. Literature states because bacterial decay occurs only within certain temperature and moisture content ranges, submerging wood in water-saturated mud for a certain period might delay decay by saturating the wood's interior cells beyond its moisture decay range [38, 39]. This phenomenon was not yet investigated in a scientific approach which confines a research gap as follows. Prolonged exposure to mud or the mud water mix simply makes the wood fibres undesirable to fungi and especially to insects as a food source. Different extracts added to the mixture get dissolved in water/fermented and create biopolymers that penetrate the timber and coat the cells. Nano or micro-level insertion of different chemicals in the mud-water mixture changes the chemical and physical structure of the wood cells. The study investigates this phenomenon and tries to grab the hidden science to further develop and reinvent a preservation technique based on this decoded knowledge from history.

4. Conclusion

This study highlights insights towards construction professionals on facts proved on environmental innovations concerning a case-based study in Sri Lanka. Moreover, old buildings contain a set of authentic information that the future should disclose. They have materialized centuries ago that uphold the technologies of those who lived in different social structures in a particular context in Sri Lanka. The survey documented a few preservation techniques practiced in the structures constructed below 20–50 years. According to the overall analysis of the identification of traditional vernacular timber preservation technologies, woods buried under paddy field mud for a considerable period was the most known method of the interviewers and it seemed to successfully come through many generations. The technologies have transferred through oral knowledge and some were developed accordingly. This study detects multiple exotic plant species, including *Tithonia diversifolia, Mikania micrantha,* and *Gliricidia sepium* for further development of the mud before submerging the wood. The survey's main finding decodes the wood submerged under paddy fields to extend its user life. The authors recommend this approach provides versatility in various fields in which a wood preservative is utilized with less environmental impact; therefore, the study highlights the requirement of further deep investigations on wood treated under paddy field mud accompanied by different plant species.

Ethics statement

The research described in this manuscript was conducted in accordance with the ethical principles outlined. Informed consent was obtained from all participants involved in the study, and they were provided with information regarding the nature and purpose of the research, its benefits, and their rights as interviewers. All dealings were carried out with the utmost respect for the well-being and confidentiality of the participants was maintained.

CrediT authorship contribution statement

M.S. Mendis: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Wasudha Abeyrathna:** Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Formal analysis. **R.U. Halwatura:** Writing – review & editing, Writing – original draft, Supervision. **H.S. Amarasekara:** Writing – review & editing, Supervision. **R. Somadewa:** Writing –

Table 6
Identify the opinions on the effectiveness of the known wood preservative technique.

	Insect repellent					Fungi repellent					Environmentally friendly					Coloring capability					Cost-Effective				
	SD	D	N	A	SA	SD	D	N	A	SA	SD	D	N	A	SA	SD	D	N	A	SA	SD	D	N	A	SA
Smoke pits	2	0	3	1	2	1	1	0	2	4	0	0	1	3	4	0	2	1	5	1	0	0	2	6	0
Paddy field mud	1	2	3	30	98	3	2	5	90	34	1	1	2	10	120	0	1	3	7	123	1	1	2	97	33
Riverbanks	0	1	1	4	6	0	1	2	6	3	0	2	1	7	2	1	2	6	2	1	1	2	6	1	2

Table 7
Summary of the rank question- Reasons for avoiding using wood preservatives.

Reason	Rank
The process is hard	1
Time-consuming	4
Heavy odor	3
Needs a paddy field	2

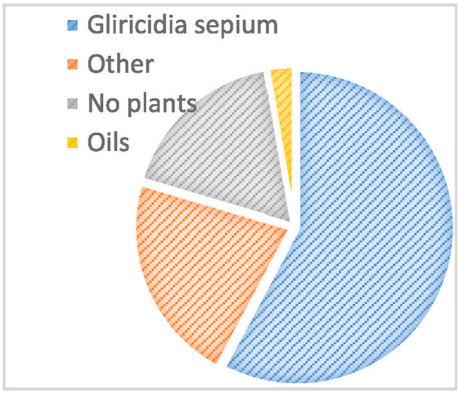


Chart 1. Plant species used to develop the paddy field mud.

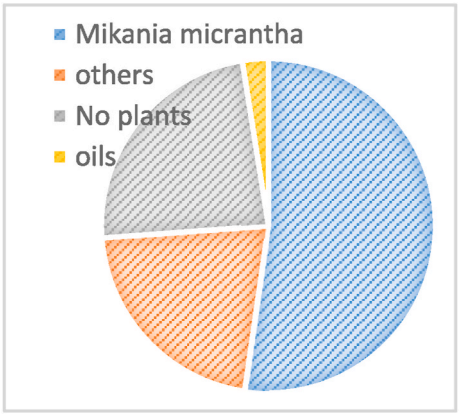


Chart 2. Plant species used to develop the paddy field mud.

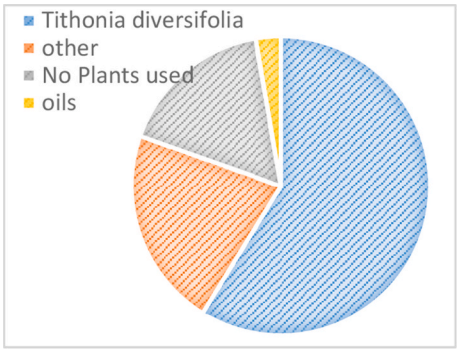


Chart 3. Plant species used to develop the paddy field mud before utilization.

Table 8
Use of traditional timber species for construction.

Timber Species	Common Name	Characteristics	Uses
Dipterocarpus zeylanicus	Satinwood	Hard, durable, termite-resistant, yellow-brown color	Beams, rafters, flooring, furniture
Hopea cordifolia	Dun	Hard, termite-resistant, reddish-brown color	Beams, rafters, columns, flooring
Mesua ferrea	Ironwood	Extremely hard, termite-resistant, dark brown color	Beams, columns, flooring, furniture
Mangifera zeylanica	Kohomba	Hard, termite-resistant, yellow-brown color	Beams, rafters, flooring, furniture
Chloroxylon swietenia	Burutha	Hard, termite-resistant, light brown color	Beams, rafters, columns, flooring
Calophyllum inophyllum	Poon	Hard, termite-resistant, yellow-brown color	Beams, rafters, flooring, furniture
Artocarpus heterophyllus	Jak	Hard, termite-resistant, reddish-brown color	Flooring, furniture, doors, windows
Mesua ferrea	Nadun	Hard, termite-resistant	Beams, rafters, pillars, furniture
Diospyros embryopteris	Ebony	Hard, termite-resistant	Flooring, furniture, carving

review & editing, Supervision. **R. Jayasinghe:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] G.L.F. Benachio, M. do C.D. Freitas, S.F. Tavares, Circular economy in the construction industry: a systematic literature review, J. Clean. Prod. 260 (2020), 121046.
[2] M. Veljkovic, H. Koukkari, R.P. Borg, V. Stoian, Z. Plewako, Overview on eco-efficiency of constructions, in: COST Action C25 FINAL CONFERENCE: 3rd-5th February 2011, Univeristy of Innsbruck, Austria, 2011, pp. 177–187.
[3] O.E. Ogunmakinde, W. Sher, K. Maund, "Circular Construction: Opportunities and Threats," in 2017 Project Management Symposium, 2017, pp. 4–5.
[4] C.K. Chau, F.W.H. Yik, W.K. Hui, H.C. Liu, H.K. Yu, Environmental impacts of building materials and building services components for commercial buildings in Hong Kong, J. Clean. Prod. 15 (18) (2007) 1840–1851.
[5] M.S. Mendis, R.U. Halwatura, D.R.K. Somadeva, R.A. Jayasinghe, Spectroscopic determination of chemical elements on abundantly available five leaf types in tropics, in: 9TH YSF SYMPOSIUM, 2020, p. 31.
[6] M. Mendis, R. Halwatura, Possible Cellular Structural and Chemical Changes of Timber under Water, 2019, https://doi.org/10.13140/RG.2.2.28431.53929.
[7] D. D.M.N.A, M. Mendis, R. Halwatura, Investigation on Chemical Insertion and Physical Property Changes of Sunken Timber; Terminalia Arjuna along with River Water in Sri Lanka, 2019.
[8] Being Tectonic: Social Innovation Through Mud-concrete (MC) Technology - IEEE Conference Publication." https://ieeexplore.ieee.org/abstract/document/9037630 (accessed May 5, 2020).
[9] A. Takano, S.K. Pal, M. Kuittinen, K. Alanne, M. Hughes, S. Winter, The effect of material selection on life cycle energy balance: a case study on a hypothetical building model in Finland, Build. Environ. 89 (2015) 192–202.
[10] D. Dissanayake, M.S. Mendis, G.Y. Jayasinghe, R.U. Halwatura, Utilization of Sustainable Timber Materials for Innovative Green Building Solutions, 2019.
[11] K. Bossardi, Tall oil e seus subprodutos: alternativas como preservantes para madeira, 2014.
[12] M.H. Ramage, et al., The wood from the trees: the use of timber in construction, Renew. Sustain. Energy Rev. 68 (2017) 333–359.
[13] M. S. Mendis, R. Arooz, and R. U. Halwatura, "SOCIAL INNOVATION THROUGH MUD-CONCRETE (MC) TECHNOLOGY," p. 5.
[14] D. Sudeshika, M. Mendis, R. Halwatura, Investigation on the Mechanical Property Variation on Timber Caused Due to the Thermal and Chemical Modification, 2020, https://doi.org/10.1109/MERCon50084.2020.9185330.
[15] M. Mendis, R. Arooz, R. Halwatura, Being Tectonic: Social Innovation through Mud-Concrete, MC) Technology, 2019, p. 5, https://doi.org/10.1109/FITI49428.2019.9037630.
[16] D.M.P. Sudeshika, M.S. Mendis, R.U. Halwatura, A Study on Most Abundantly Utilized Timber for Structural Application in Sri Lanka, 2019.
[17] M.S. Mendis, M. Rajapaksha, R.U. Halwatura, Unleashing the potentials of traditional construction technique in bioclimatic building designs: a case of Ambalam Sri Lanka, Int. J. Env. Sci. Dev. 11 (6) (2020).
[18] M.S. Mendis, R. Umesh Halwatura, Decoding the societal transitions on environmental innovation under vernacular timber construction practice in Sri Lanka, in: 2019 from Innovation to Impact (FITI), Nov. 2019, pp. 1–6, https://doi.org/10.1109/FITI49428.2019.9037628.
[19] M. Agnoletti, Rural landscape, nature conservation and culture: some notes on research trends and management approaches from a (southern) European perspective, Landsc. Urban Plann. 126 (Jun. 2014) 66–73, https://doi.org/10.1016/j.landurbplan.2014.02.012.
[20] S. Jasanoff, States of Knowledge: the Co-production of Science and the Social Order, Routledge, 2004.
[21] G.S. Aikenhead, M. Ogawa, Indigenous knowledge and science revisited, Cult. Stud. Sci. Educ. 2 (3) (Jul. 2007) 539–620, https://doi.org/10.1007/s11422-007-9067-8.
[22] R.M. Keesing, Theories of culture, Annu. Rev. Anthropol. 3 (1) (1974) 73–97, https://doi.org/10.1146/annurev.an.03.100174.000445.
[23] R. Tsosie, Tribal environmental policy in an era of self-determination: the role of ethics, economics, and traditional ecological knowledge, Vt Rev. 21 (1996) 225.
[24] S. Pilgrim, et al., The intersections of biological diversity and cultural diversity: towards integration, Conserv. Soc. 7 (2) (2009) 100, https://doi.org/10.4103/0972-4923.58642.
[25] R. Tsosie, Tribal environmental policy in an era of self-determination: the role of ethics, economics, and traditional ecological knowledge, Vt. Law Rev. 21 (1997 1996) 225 [Online]. Available: https://heinonline.org/HOL/Page?handle=hein.journals/vlr21&id=239&div=&collection=.
[26] H. Rolston, Nature and culture in environmental ethics, in: Proceedings of the Twentieth World Congress of Philosophy, Philosophy Documentation Center, 1999, pp. 151–158, https://doi.org/10.5840/wcp20199919.
[27] M. Mendis, R. Halwatura, Decoding the Societal Transitions on Environmental Innovation under Vernacular Timber Construction Practice in Sri lanka, 2019, p. 6, https://doi.org/10.1109/FITI49428.2019.9037628.

[28] M. Mendis, R. Halwatura, D.R.K. Somadeva, R.A. Jayasinghe, M. Gunawardana, Influence of grain distribution on orientation of saw cuts; Reference to heritage structures, Case Stud. Constr. Mater. 11 (Apr) (2019), https://doi.org/10.1016/j.cscm.2019.e00237.
[29] THE HISTORY OF BUDDHIST ARCHITECTURE IN SRI LANKA." http://ccbs.ntu.edu.tw/FULLTEXT/JR-AN/an027_4.htm (accessed January 22, 2022).
[30] B.A. Richardson, Wood Preservation, Routledge, 2002.
[31] International Symposium on Wood Preservation "The Challenge Safety–Environment" et al, Wood Preservation: [2nd International Symposium on Wood Preservation the Challenge, Safety–Environment], 8-9 Fe?vrier 1993, Cannes-Mandelieu, France, IRG Secretariat, Stockholm, Sweden, 1993. Sep. 14, 2021. [Online]. Available: https://www.taylorfrancis.com/books/e/9780203474037.
[32] C.A.S. Hill, Wood Modification: Chemical, Thermal and Other Processes, John Wiley & Sons, 2007.
[33] D.I. Hurtado, S. Nocua, W. Narváez, J. Vargas, Valor nutricional de la morera (Morus sp.), matarratón (Gliricidia sepium), pasto India (Panicum máximum) y arboloco (Montanoa quadrangularis) en la alimentación de cuyes (Cavia porcellus), Rev. Vet. Zootec. (Manizales) 6 (1) (2012) 56–65.
[34] S.F. Silva, et al., Agronomic characteristics and chemical composition of Gliricidia sepium grown under different residual heights in different seasons, Cienc. E Investig. Agrar. Rev. Latinoam. Cienc. Agric. 44 (1) (2017) 35–42.
[35] A.R. Macanawai, M.D. Day, T. Tumaneng-Diete, S.W. Adkins, F. Nausori, Vegetative growth and development of Mikania micrantha in taro and cassava production in Viti Levu, Fiji, in: in 23 rd Asian-Pacific Weed Science Society Conference, 2011, p. 322.
[36] S. Vijayan, C.M. Joy, Growth measurements of invasive plant Mikania micrantha Kunth (mile a minute weed), A threat of biodiversity, Int. J. Plant Environ. 5 (1) (2019) 23–25.
[37] D.A. Agboola, W.F. Idowu, M. Kadiri, Seed germination and seedling growth of the Mexican sunflower Tithonia diversifolia (Compositae) in Nigeria, Africa, Rev. Biol. Trop. 54 (2) (2006) 395–402.
[38] S.H. Senarathne, A.J. Atapattu, T. Raveendra, S. Mensah, K.B. Dassanayake, Biomass allocation and growth performance of Tithonia diversifolia (Hemsl.) A. Gray in coconut plantations in Sri Lanka, Agrofor. Syst. 93 (5) (2019) 1865–1875.
[39] D. Dissanayake, M.S. Mendis, G.Y. Jayasinghe, R.U. Halwatura, A study on chemical insertion and physical property changes of sunken timber; Terminalia arjuna along with river water in Sri Lanka, IOSR J. Environ. Sci. Toxicol. Food Technol. 14 (1) (2020) 54–69.