

Research Article

Sustainability and Sacred Forests: The Cultural-Ecological Role of the Phutai People's Forest in Kalasin, Thailand

Rattana Phonkla Tunwa Chaitieng* and Theeranat Suwannarueng Chuthamat Chiamsathit

Science and Environmental Health Department, Science and Health Technology Faculty, Kalasin University,
SongPluay Sub-district, Namon District, Kalasin Province 46230, Thailand

(Received: January 26, 2025; Revised: April 10, 2025; Accepted: August 24, 2025)

ABSTRACT

This study examines the Khambong spiritual forest, focusing on its connection to nature, culture, and sustainability. The forest reflects the Phutai community's spiritual beliefs and close bond with the natural world. It hosts 45 tree species from 24 families, with *Castanopsis piriformis* Hickel & A. Camus playing a key role in its ecosystem. The forest provides critical ecological services, sequestering 156.76 tC/ha of carbon and producing 1,003.27 tO₂, significantly contributing to climate regulation. Additionally, it contains 29 medicinal species and 7 species used for both medicine and food, preserving traditional knowledge and supporting local well-being. These findings highlight the forest's importance and offer guidance for sustainable management strategies. The Khambong spiritual forest demonstrates the balance needed for resilient ecosystems and provides a model for integrating cultural wisdom with modern conservation methods. Further studies are encouraged to explore its adaptability and long-term ecological and cultural contributions.

Key words: Khambong spiritual forest, Phutai community, Carbon sequestration, Traditional knowledge, Sustainable forest management

INTRODUCTION

Climate change poses a unique challenge unlike anything humanity has faced before. It stems largely from the rapid rise in greenhouse gas emissions. The effects extend well beyond the climate itself, causing widespread harm to ecosystems and profoundly impacting communities across the globe (Babcock *et al.*, 2019). The combination of rising sea levels and the ongoing loss of biodiversity highlights the critical need for unified, long-term efforts to tackle this escalating environmental crisis (WHO, 2020).

Scientific and technological advancements have driven industrialization, economic growth, enhanced transportation, and significant progress in healthcare. However, these benefits have also led to a rise in greenhouse gas emissions, a key factor contributing to global challenges like climate change (Oliveira & Queiroz, 2020). Tackling this issue requires a range of strategies. One highly effective approach involves engaging communities through tree planting and forest conservation (Bonan, 2008). Both afforestation and reforestation are vital for carbon capture, proving that nature-based solutions can help mitigate global warming and support sustainable development. However, relying solely on tree planting or forest preservation for carbon sequestration is not sufficient (Keith *et al.*, 2021; Seddon *et al.*, 2021). Even with government management and national park designation, forest degradation remains a critical issue. In Southeast Asia, wildfires exacerbate this problem, causing severe damage to ecosystems and impacting local communities (Tacconi *et al.*, 2007; Vadrevu *et al.*, 2019). As highlighted by

Lowman and Sinu (2017), forests are dynamic ecosystems that integrate both biological and cultural elements. They provide essential habitats for biodiversity while holding deep spiritual value for communities worldwide. Our study focuses on the Phutai spiritual forest in Khambong village, Kalasin province, exploring its roles in oxygen generation, carbon storage, and the provision of diverse food and medicinal plants. Previous research has underscored the remarkable biodiversity and ecological significance of northeastern Thailand's community forests and sacred groves (Chaitieng, 2017; Chaitieng & Srisatit, 2013). By focusing on the relationships between spiritual forests, their ecological roles, and their cultural importance, our study addresses a notable gap in the existing literature. While much of the current research remains theoretical, recent studies have begun exploring the evolving spiritual values of forests across Europe and Asia. There is a growing trend toward rediscovering and reconnecting with forest spirituality (Lowman & Sinu, 2017; Roux *et al.*, 2022). The complex interconnections between spirituality, ecology, and the practical benefits provided by forests remain poorly understood. This is especially true for unique spiritual forests like those of the Phutai people. Existing research on carbon sequestration in sacred forests, while insightful, does not fully address the broader integration of ecosystem services and the cultural importance of the Phutai spiritual forest in Kalasin province, Thailand. A key research gap lies in the medicinal resources found in spiritual forests, particularly in the sacred groves of the Phutai, one of the oldest ethnic groups in the Mekong region, which our study seeks to address (Chaitieng & Srisatit, 2013; Pandey, 2022; Maru *et al.*, 2023). This study aims to deepen

*Corresponding Author's E-mail: parivuthagul@yahoo.com



Figure 1. Location of Area Study : Hui Phueng district, Kalasin Province, Thailand

our understanding of the food and medicinal resources provided by these sacred forests, along with the ecosystem services they offer, particularly focusing on carbon storage. Centered on the Phutai community, a prominent indigenous group in Kalasin province, Thailand, the research highlights the critical ecological and cultural roles of these unique forested areas. By examining the intricate dynamics of this spiritual forest, we strive to provide valuable insights that can guide sustainable forest management, balancing the preservation of cultural heritage with ecological conservation (Lowman & Sinu, 2017; Pandey, 2022). Our study highlights the significant role of the Phutai spiritual forest in preserving cultural heritage while also delivering vital ecosystem services. By exploring its complex dynamics, we aim to promote sustainable forest management practices that harmonize ecological conservation with the protection of cultural traditions.

MATERIAL AND METHODS

Study site

The research was conducted in the Spiritual forest located in the Phutai village within Kalasin, situated in the lower Mekong basin. Specifically, the study focused on Khambong village, Hui Phueng District, Kalasin province, Thailand, positioned at approximately latitude $16^{\circ} 39' 12.67''$ N and longitude $103^{\circ} 50' 48.76''$ E. (Fig.1) The region experiences an average annual temperature of 27.4°C , ranging from 11.5°C to 42.3°C . The average annual rainfall is 1,398.4 mm, with the rainy season typically spanning from April to October.

The Phutai spiritual forest in Khambong village is categorized as a dry evergreen forest, a characteristic of tropical rainforests. Located within the village and surrounded by local roads, this sacred woodland plays an integral role in the community's social and cultural fabric (Fig. 2).

Tree inventories

This study can be broken down into as follows;

Examining the spiritual forest involved analyzing the distribution of the Phutai people and the placement of their sacred woodland. In-depth interviews with key members of the Phutai community were conducted as part of the primary data collection process. These discussions provided valuable qualitative insights into cultural values, traditional knowledge of medicinal and food-producing trees, and ecological perspectives.

Plant sampling was conducted using three 40×40 m plots. Tree species meeting the criteria of DBH (Diameter at Breast Height) ≥ 4.5 cm and height ≥ 1.30 m were recorded. Measurements of height and diameter were taken using a Haga Altimeter, a measuring pole, and a diameter tape. Additionally, interviews with community leaders provided valuable insights into the usefulness of each tree.



Figure 2. Spiritual forest of Khambong Kalasin, showcasing the encroachment of housing, agriculture and transport infrastructure (Google Earth capture at eye-height of 973 m. on October 10, 2024)

Data Analysis

Estimation tree biomass: Aboveground biomass was calculated by summing the stem, branches and leaf mass of individual trees, using allometric equation developed by Tsutsumi *et al.* (1983) for trees in dry evergreen forest and allometric equation developed by Wiriyabunchachai (2003) for vines biomass as the following:

Allometric equation developed by Tsutsumi *et al.* (1983)

$$\begin{aligned} \text{stem biomass } (WS) &= 0.0509 * (D^2H)^{0.919} \\ \text{branch biomass } (WB) &= 0.00893 * (D^2H)^{0.977} \\ \text{leaf biomass } (WL) &= 0.0140 * (D^2H)^{0.669} \end{aligned}$$

Allometric equation developed by Wiriyabunchachai (2003)

$$\text{aboveground biomass} = 0.862 * (D)^{2.0210}$$

where H = tree height (m), D = DBH, diameter breast height (m), Ws= stem biomass (Kg/individual tree) Wb= branch biomass (Kg/individual tree) Wl= leaf biomass (Kg/individual tree)

Estimation of belowground biomass: Calculation of belowground biomass (BGB) involved using the root-to-shoot ratio, with a value of 0.26 derived from aboveground biomass (Cairns *et al.*, 1997)

Total biomass, carbon sequestration and carbon dioxide absorption: Total biomass, encompassing both aboveground and belowground biomass, was determined. carbon content was computed by applying a conversion factor of 0.47 to the total biomass. (Brown & Lugo, 1982; Chaiyo *et al.*, 2011).

To estimate carbon dioxide absorption, a conversion factor of 3.67 was applied to Carbon Sequestration (Manuri *et al.*, 2011; Keerthika & Chavan, 2022)

Importance value index (IVI): IVI was calculated summing the relative density, relative frequency and relative dominance (Curtis, 1959; Hariyadi & Maddappa, 2021)

Relative density = Number of individual of the species x 100/Number of individual of all the species

Relative frequency = Number of occurrence of the species x 100/Number of occurrence of all the species

Relative dominance = Total basal area of the species x 100/Total basal area of all the species

Oxygen Production by trees

The quantification of oxygen generated through carbon sequestration involves the utilization of atomic weights. When the carbon uptake surpasses the carbon dioxide released in respiration during photosynthesis, carbon accumulates within the tree. The computation of net oxygen production is determined by the formula outlined.

Net O₂ release (kg yr⁻¹) = Net C sequestration (kg yr⁻¹) x 32 / 12 (Keerthika & Chavan, 2022; Nowak *et al.*, 2007; Sprugel *et al.*, 1995; Ramanan, 2022)

The analysis of medicinal and food plants was based on interviews with traditional healers, where plants were categorized into medicinal, food, and dual-purpose species. The data was analyzed for frequency and patterns of use, then cross-referenced with field surveys to confirm species presence (Cunningham, 2014; Gerique, 2006; Nolan, & Turner, 2011).

RESULTS AND DISCUSSION

Spiritual Forest: History and Relationship with the Community

The Tai-Kadai-speaking Phutai community has a rich and intriguing history rooted in the lower Mekong River Basin. Originating in southern China, they migrated through northern Vietnam before eventually settling in the central region of the Lao People's Democratic Republic. Around 1826, they made a significant migration to Kalasin province in Thailand. Today, most Phutai people in the province reside near mountainous areas, particularly in districts such as Khao Wong, Na Khu, Huai Phung, Kuchinarai, Somdet, and Kham Muang.

The Phutai people of Khambong have long upheld beliefs in spirits residing within nature, including mountains, forests, and their village. Their lives are deeply shaped by respect and humility toward the natural world. In 1885, upon founding the village, they designated a nearby forest as sacred for community rituals. They invited spirits to dwell in a modest shrine (Fig. 3), serving as ancestral guardians to protect the community and ensure harmony for future generations. After each harvest, they offer gratitude to these spirits. For over 138 years, the community has preserved this spiritual forest, honoring its sacredness and fostering a profound connection with the land. This forest remains a ritual site and a haven for native plants, safeguarding its biodiversity.

Plant Species and Tree Dominance in the Spiritual

The Khambong spiritual forest is classified as a dry evergreen forest, covering 15 rai (2.4 hectares; 6.25 rai equals 1 hectare) of a unique ecosystem (Figs. 4-5). This sacred forest hosts 346 trees, encompassing 45 tree species, 37 genera, and 24 families, with two species yet to be identified.

The Khambong spiritual forest is a dry evergreen forest spanning 15 rai (2.4 hectares, with 6.25 rai equaling 1 hectare) (Figs. 3-4). This unique ecosystem contains 346 individual trees, representing 45 species, 37 genera, and 24 families, with two species yet unidentified.



Figure 3. The spirit shrine in the forest, where the Phutai people perform rituals before and after rice cultivation, is a simple and natural structure, even though it is now larger compared to the earlier shrine.

The Fabaceae family is prominent with six species, notably *Castanopsis piriformis* Hickel & A. Camus. The Dipterocarpaceae family includes five species, with *Anisoptera costata* Korth. as the key species, while the Annonaceae family has four species, including *Uvaria dac* Pierre ex Finet & Gagnep. These native flora, particularly Fabaceae, Dipterocarpaceae, and Annonaceae, are well adapted to the environment, making them dominant in the region's sacred forests.

Castanopsis piriformis Hickel & A. Camus exhibits the highest Importance Value Index (IVI) among the recorded species, scoring 31.40. Close contenders include *Nephelium hypoleucum* Kurz. (23.20), *Anisoptera costata* Korth. (22.63), *Ficus benjamina* L. (18.59), and *Uvaria dac* Pierre ex Finet & Gagnep. (16.91), as shown in Table 1. The dominance of *Castanopsis piriformis* is further underscored by its top IVI value, confirming it as the most abundant species in the study area (Table 1).

Prominent trees in the Khambong spiritual forest, including *Castanopsis piriformis* Hickel & A. Camus, *Nephelium hypoleucum* Kurz., and *Anisoptera costata* Korth., represent traditional species no longer found elsewhere in the community. This sacred forest has safeguarded native plant species of Northeastern Thailand since before industrial factories, such as sugar and starch mills, were established in Kalasin Province. These industries promoted monoculture farming of crops like sugarcane and cassava, leading to deforestation and the loss of biodiversity. Such environmental shifts became widespread as Thailand embraced agricultural industrialization, particularly after the green revolution.

Biomass, Carbon Storage, and Oxygen Production

Photosynthesis, an ongoing process in

Table 1. Tree species, importance value index, carbon stock, oxygen production, and value of trees in Kham Bong spiritual forest

Family	Scientific name	IVI	Carbon Stock tC/ha	O ₂ production tO ₂ /ha	Value
ANACARDIACEAE	<i>Lannea coromandelica</i> (Houtt.) Merr.	2.13	1.06	2.83	skin diseases
ANACARDIACEAE	<i>Spondias pinnata</i> (L.f.) Kurz.	1.67	0.30	0.80	treat diarrhea (bark), cooking (fruit)
ANNONACEAE	<i>Polyalthia viridis</i> Craib.	7.56	2.80	7.47	-
ANNONACEAE	<i>Melodorum fruticosum</i> Lour.	3.44	0.12	0.32	treat fever (leave)
ANNONACEAE	<i>Goniothalamus laoticus</i> (Finet & Gagnep.) Ban.	11.27	1.44	3.84	promotes Lactation (root/bark)
ANNONACEAE	<i>Uvaria dac Pierre ex Finet & Gagnep.</i>	16.91	2.67	7.12	food (fruit)
APOCYNACEAE	<i>Alstonia scholaris</i> (L.) R. Br.	3.36	3.04	8.11	controlling blood sugar levels (bark)
ARECACEAE	<i>Arenga pinnata</i> (Wurmb) Merr.	1.55	0.03	0.08	food (fruit)
AURANTIOIDEAE	<i>Micromelum minutum</i> Wight & Arn.	1.70	0.30	0.80	treating asthma (root)
BETULACEAE	<i>Betula alnoides</i> Buch.-Ham. ex D.Don.	2.87	2.76	7.36	body tonic (bark, root)
BIGNONIACEAE	<i>Dolichandrone serrulata</i> (Wall. ex DC.) Seem.	1.53	0.02	0.05	asthma and colds (root)
BURSERACEAE	<i>Garuga pinnata</i> Roxb.	5.19	1.60	4.27	treat diarrhea (leave & bark)
CHRYSOBALANACEAE	<i>Parinari anamense</i> Hance.	3.95	0.32	0.85	anti-inflammatory (bark) food (fruit)
DIPTEROCARPACEAE	<i>Anisoptera costata</i> Korth.	22.63	32.28	86.08	-
DIPTEROCARPACEAE	<i>Dipterocarpus alatus</i> Roxb. ex G.Don	3.29	4.28	11.41	treatment for skin diseases (resin oil)
DIPTEROCARPACEAE	<i>Hopea ferrea</i> Laness.	2.13	1.11	2.96	prevent loose teeth
DIPTEROCARPACEAE	<i>Hopea odorata</i> Roxb.	3.74	0.66	1.76	treat gum inflammation
DIPTEROCARPACEAE	<i>Shorea obtusa</i> Wall. ex Blume.	1.66	0.21	0.56	treat chronic wounds
EBENACEAE	<i>Diospyros castanea</i> Fletcher.	2.10	0.43	1.15	antiparasitic
EBENACEAE	<i>Diospyros mollis</i> Griff.	2.56	0.24	0.64	antiparasitic
EBENACEAE	<i>Diospyros rhodocalyx</i> Kurz.	2.21	1.00	2.67	sexual performance (heart wood)

Cultural-Ecological Role of the Phutai People's Forest

EUPHORBIACEAE	<i>Croton persimilis</i> Müll.Arg.	1.54	0.01	0.03	treat diarrhea (bark and leaves)
FABACEAE	<i>Adenanthera pavonina</i> L.	2.12	0.34	0.91	treat wounds, abscesses (seed)
FABACEAE	<i>Azelia xylocarpa</i> (kurz) Craib.	3.46	0.18	0.48	parasitic infection (trunk)
FABACEAE	<i>Dalbergia assamica</i> Benth.	4.34	1.13	3.01	antipyretic
FABACEAE	<i>Dalbergia oliveri</i> Gamble.	5.16	1.82	4.85	nourish the blood
FABACEAE	<i>Dialium cochinchinense</i> Pierre.	9.13	5.21	13.89	food (fruit)
FABACEAE	<i>Sindora siamensis</i> Teijsm. ex Miq.	3.12	0.10	0.27	treat hemorrhoids (bark)
FAGACEAE	<i>Castanopsis piriformis</i> Hickel & A. Camus.	31.40	10.87	28.99	food (fruit)
GUTTIFERAE	<i>Garcinia cowa</i> Roxb. ex DC.	6.48	1.33	3.55	purify the blood, food (leave)
IRVINGIACEAE	<i>Irvingia malayana</i> Oliv. ex A.W.Benn.	2.58	1.83	4.88	nourish the tendons, food (fruit)
LECYTHIDACEAE	<i>Careya sphaerica</i> Roxb.	5.72	2.44	6.51	strengthening medicine (flower)
LYTHRACEAE	<i>Lagerstroemia calyculata</i> Kurz.	13.05	14.23	37.95	delirium tremens (bark)
MELASTOMATACEAE	<i>Memecylon edule</i> Roxb.	8.38	1.25	3.33	stomach ulcers (root)
MORACEAE	<i>Artocarpus lakoocha</i> Roxb. ex Buch.-Ham.	1.59	0.09	0.24	anthelmintic properties (wood)
MORACEAE	<i>Ficus benjamina</i> L.	18.59	26.33	70.21	blood tonic (air root)
MORACEAE	<i>Streblus asper</i> Lour.	10.04	6.12	16.32	gum disease (bark) food (fruit)
PHYLLANTHACEAE	<i>Baccaurea ramiflora</i> Lour.	8.48	1.12	2.99	diarrhea (root) food (fruit)
RUBIACEAE	<i>Haldina cordifolia</i> (Roxb.) Ridsdale.	1.93	0.66	1.76	skin disease (root)
SAPINDACEAE	<i>Lepisanthes rubiginosa</i> (Roxb.) Leenh.	5.09	0.55	1.47	boost vitality, food (fruit)
SAPINDACEAE	<i>Nephelium hypoleucum</i> Kurz.	23.20	13.62	36.32	common cold, food (fruit)
TILIACEAE	<i>Microcos tomenosa</i> Smith.	5.86	0.91	2.43	asthma (wood)
TILIACEAE	<i>Schoutenia ovata</i> Korth.	13.93	8.55	22.80	-
Unknown	Unidentified	7.70	0.59	1.57	-
Unknown	Unidentified	3.66	0.81	2.16	-

*Md= Medicinal Plant, Md&F = Medicinal Plant and Food Plant, F = Food Plant

plants, continuously removes carbon dioxide from the atmosphere while releasing oxygen back into it. In our analysis of carbon sequestration, carbon dioxide absorption, and oxygen production, tree biomass was utilized. In the Phutai people's spiritual forest in Khambong, the average above-ground biomass was calculated at 264.71 tons per hectare (t/ha), supplemented by 68.82 t/ha of below-ground biomass, resulting in a total biomass of 333.53 t/ha.

The carbon sequestration for above-ground components averaged 124.41 tC/ha, while below-ground components accounted for 32.35 tC/ha, culminating in a combined total of 156.76 tC/ha. For the entire forest, carbon sequestration reached 376.22 tC, with an estimated total carbon dioxide absorption of 1,380.73 tons.

Regarding oxygen release, each tree in the forest contributed an average of 418.03 tO₂/ha. Altogether, the trees in the Khambong spiritual forest produced a total of 1,003.27 tO₂.

Figure 6 The study reveals a significant correlation between the important value index (IVI), carbon stock, and oxygen (O₂) production, suggesting a strong interrelation among these indicators. Families with higher IVI, such as Dipterocarpaceae and Moraceae, exhibit greater carbon content, carbon equivalent, and O₂ generation. These findings highlight the influential role of tree diameter, density, and frequency in determining the amount of carbon stored and O₂ produced. However, despite *Castanopsis piriformis* Hickel & A. Camus having the highest Importance Value Index (IVI), which is a species in the Fagaceae family, this family is represented by only one species.

Medicinal and Food Plants in the Spiritual Forest

The spiritual forest, cherished by the Phutai community in the picturesque village of Khambong, Thailand, carries profound importance that surpasses its contributions to carbon sequestration and oxygen production. Out of the 45 plant species documented in the Khambong spiritual forest, 43 were successfully identified. Local indigenous knowledge highlights that 29 of these species possess medicinal properties and are used to treat various ailments. Notable examples include *Lanea coromandelica* (Houtt.) Merr., *Melodorum fruticosum* Lour., *Goniothalamus laoticus* (Finet & Gagnep.) Ban., *Alstonia scholaris* (L.) R. Br., *Micromelum minutum* Wight & Arn., *Hopea ferrea* Laness., and *Microcos tomentosa* Smith.

Different parts of these plants, such as bark, leaves, heartwood, and roots, serve diverse purposes. Additionally, 7 species are known for their dual use in both medicinal and culinary applications, including *Spondias pinnata* (L.f.) Kurz., *Parinari anamense* Hance., *Irvingia malayana* Oliv. ex A.W. Benn., *Baccaurea ramiflora* Lour., and *Nephelium hypoleucum* Kurz. These species are valued for their dual use in both herbal medicine and food, with most of the culinary applications involving their fruit. Among the identified species, four are exclusively fruit-bearing trees: *Uvaria dac* Pierre ex Finet & Gagnep., *Arenga pinnata* (Wurmb) Merr., *Dialium cochinchinense* Pierre, and *Castanopsis piriformis* Hickel & A. Camus (Table 1).

However, before extracting any resources from the forest, it is essential to perform a ritual to inform and seek permission from the spirits or sacred entities that protect the forest.



Figure 4-5. Khambong spiritual forest and Plant community

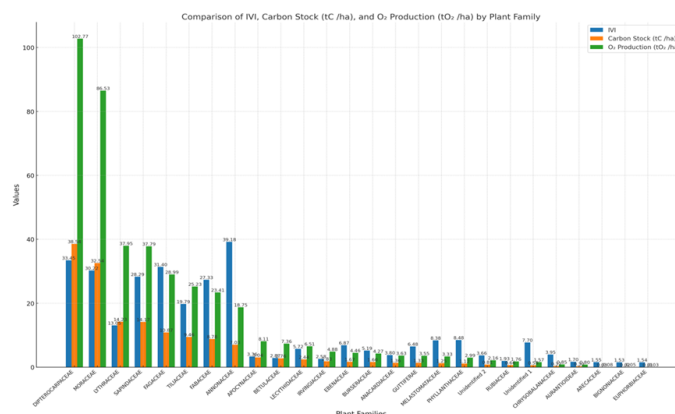


Figure 6. Relative Contributions of Plant Families to IVI, Carbon Stock (tC/ha), and O₂ Production (tO₂/ha) in Spiritual forest



Figure 7. *Uvaria dac* Pierre ex Finet & Gagnep food plant of man and animals

Undoubtedly, the spiritual forest in Khambong village, cherished by the Phutai people, serves as a testament to the untapped potential of medicinal and food plants, forming the foundation of the community's health security system and ensuring food safety.



Figure.8 Spiritual forest “Bank of Medicinal-Food plants” of Phutai community

Table 1 presents the key findings on tree species in the Khambong spiritual forest, highlighting their Importance Value Index (IVI), carbon storage, oxygen production, and significance to the local community. The forest supports diverse species, including *Castanopsis piriformis* Hickel & A. Camus from the Fagaceae family and *Nephelium hypoleucum* Kurz from the Sapindaceae family, both recognized for their high IVI scores and ecological contributions. The Dipterocarpaceae family, known for its towering trees, includes species such as *Dipterocarpus alatus* Roxb. ex G.Don and *Anisoptera costata* Korth., which play critical roles in carbon storage. Additionally, *Irvingia malayana* Oliv. ex A.W.Benn., *Streblus asper* Lour., and *Parinari anamense* Hance are valued for their dual use in medicine and food, offering significant benefits to the community. These plants enhance the forest's role as a source of health security and nourishment. Beyond its cultural importance, the forest contributes to carbon sequestration and oxygen generation, making it an invaluable ecological resource.

This study highlights the critical roles of the Khambong spiritual forest, including its plant diversity, carbon storage, oxygen production, and importance as a source of medicinal and food plants for the local community. Building on prior research into cultural and ecological services, it underscores the need for integrated approaches to forest conservation and sustainable use. The

study delves into the deep spiritual beliefs of the Phutai community, showcasing their strong bond with nature. Consistent with studies by Chaitieng and Srisatit (2014), Suthari *et al.* (2016), Doffana (2017), and Lowman and Sinu (2017), it highlights the evolving spiritual values of forests and the cultural significance of sacred groves. The tradition of establishing sacred spaces, where spirits are invited to safeguard the community, parallels early Shinto practices in Japan. In Shinto traditions, simple rituals—such as placing stones or bending tree branches—were conducted to invite spirits, transforming the space into a sacred site for communal blessings (García & Miralles, 2020; Teeuwen & Scheid, 2002). Similarly, the Phu Thai ethnic group in Kalasin continues the ancient Tai cultural practices that emphasize nature reverence. These traditions share roots with the Zhuang people of China, tracing their heritage to the Yue civilization along the Yangtze River basin (Chaitieng & Srisatit, 2013; Shrestha *et al.*, 2020). The Khambong spiritual forest is notable for its rich ecosystem, hosting 45 tree species from 24 families, with two species yet unidentified. This aligns with studies by Chaitieng (2017), Chaitieng and Srisatit (2013), Shrestha *et al.* (2020), and Mequanint *et al.* (2020), which explored plant diversity in sacred forests across Southeast and South Asia. These studies emphasize the vital role sacred forests play in preserving native biodiversity. In northeastern Thailand, species from the Fabaceae, Dipterocarpaceae, and Annonaceae families are particularly common. Among them, *Dipterocarpus alatus* Roxb. ex G.Don holds cultural significance to the Thai royal family and has been integral to conservation efforts. Our research highlights the forest's substantial carbon sequestration capacity, averaging 156.76 tC/ha.

Sacred forests in central India, as studied by Dar *et al.* (2019), reported a lower carbon sequestration value of 97.0 tC/ha. Similarly, Chaitieng's (2017) research documented levels of 59.47 tC/ha in the sacred forests of the Tai-Yoh community in Kalasin Province, Thailand. These findings emphasize the vital connection between indigenous knowledge, cultural traditions, and the conservation of forest ecosystems. While scientific studies highlight the forests' role in carbon absorption and oxygen production, their true strength lies in how local wisdom and long-standing beliefs have naturally fostered the protection of these landscapes. What's remarkable is that these conservation efforts have flourished with minimal financial resources, sustained by the community's deep bond with nature. While the Dipterocarpaceae family provides limited food and medicinal uses, it thrives in northeastern Thailand's tropical climate, making it a valuable contributor to carbon sequestration and deserving of broader cultivation. In contrast, the Annonaceae family, despite having fewer species, holds the highest Importance Value Index and exhibits robust growth in the region, highlighting its ecological importance.

The trees in Khambong contribute significantly to the ecosystem by sequestering carbon and producing 1,003.27 tO₂. This aligns with studies by Keerthika and Chavan (2022), which highlight the role of trees in oxygen production. Furthermore, the forest's 29 medicinal species and 7 species used for both food and medicine are consistent with findings from Doffana (2017) and Suthari *et al.* (2016) in In-

dia's sacred forests, as well as Wadley and Colfer (2004) in Indonesia. While not a primary resource for daily needs, these forests act as vital reserves, providing medicinal and food supplies during economic or social crises. Such studies emphasize the critical role sacred forests play in preserving traditional knowledge of medicinal plants. Additionally, Khambong forest's role in health security and food safety aligns with Pandey's (2002) findings, which underscore the cultural and nutritional value of forest resources. The ancient trees of Khambong not only offer ecosystem services but also embody the rich historical narratives of the local community. This perspective mirrors research by Cagliero *et al.* (2022), which examines the cultural and historical significance of ancient trees in Southeast Europe.

The trees in Khambong forest stand as timeless guardians, offering vital ecological benefits while serving as living records of the community's heritage. This perspective parallels studies of ancient trees in Europe, which emphasize both their ecological and historical significance. Rot (2014) supports this view, highlighting sacred forests as environmental spaces deeply tied to the ancient beliefs of Japanese Shinto traditions. Beyond their ecological roles, such as carbon sequestration, sacred forests embody the cultural traditions of communities worldwide. The study of the Khambong spiritual forest reveals the diverse values forests hold, aligning with research on cultural, ecological, and economic aspects, and stressing the importance of holistic forest conservation strategies.

CONCLUSION

The Phutai spiritual forest in Kalasin, Thailand, showcases the connection between nature, culture, and sustainability. With 45 tree species, including *Castanopsis piriformis* Hickel & A. Camus, it stores 156.76 tC/ha and produces over 1,000 tons of oxygen, highlighting its role in climate regulation. The forest's medicinal plants preserve traditional health knowledge, supporting community well-being. This study integrates scientific research with Phutai cultural wisdom, underscoring the ecological and cultural significance of spiritual forests. Found across Asia, such forests reflect communities' harmony with nature. Beyond ecological services, they embody cultural reverence and responsible stewardship. The research calls for sustainable forest management that respects both ecology and tradition. Combining indigenous knowledge with modern conservation methods ensures these ecosystems endure. The Phutai forest stands as a model of balance between human well-being and nature.

ACKNOWLEDGEMENTS

We would like to thank the Phutai community of Ban Khambong, Khambong Subdistrict, Huai Phueng District, Kalasin Province, especially the local wisdom keepers, for their support.

REFERENCES

- Baker, C. (2002). From Yue to Tai. *Journal of the Siam Society*, 90(1-2), 1-26.
- Babcock, R. C., Bustamante, R. H., Fulton, E. A., Fulton, D. J., Haywood, M. D., Hobday, A. J., ... & Vanderklift, M. A. (2019). Severe continental-scale Impacts of climate change are happening now: Extreme climate events impact marine habitat forming communities along 45% of Australia's coast. *Frontiers in Marine Science*, 6, 466674. <http://doi.org/10.3389/fmars.2019.00411>
- Bonan, G. B. (2008). Forests and climate change: forcings, feedbacks, and the climate benefits of forests. *Science*, 320(5882), 1444-1449. <http://doi.org/10.1126/science.1155121>
- Brown, S., & Lugo, A. E. (1982). The storage and production of organic matter in tropical forests and their role in the global carbon cycle. *Biotropica*, 161-187. <http://doi.org/10.2307/2388024>
- Cagliero, E., Morresi, D., Paradis, L., Čurović, M., Spalevic, V., Marchi, N., ... & Finsinger, W. (2022). Legacies of past human activities on one of the largest old-growth forests in the south-east European mountains. *Vegetation History and Archaeobotany*, 1-16. <http://doi.org/10.1007/s00334-021-00862-x>
- Cairns, M. A., Brown, S., Helmer, E. H., & Baumgardner, G. A. (1997). Root biomass allocation in the world's upland forests. *Oecologia*, 111, 1-11. <http://doi.org/10.1007/s004420050201>
- Chaitieng, T. (2017). Sacred forest: Values and ecological potential of local plants in Taiyoh Tribe's sacred forest in Baan Nongpa-O, Kalasin Province, Thailand. *Life Sciences and Environment Journal*, 18(1), 61-71.
- Chaitieng, T., & Srisatit, T. (2013). Spiritual forest of Phutai people: The biodiversity of sacred plant and ecological-cultural values in Sakhon Nakhon Basin, Thailand. *European Scientific Journal*, 9 (32).
- Chaitieng, T., & Srisatit, T. (2014). The potential of indigenous people's forest: Ecological benefits and plants diversity in Bru People's spiritual forest, Northeastern Thailand. *British Journal of Applied Science & Technology*, 4(17), 2430-2439.
- Chaiyo, U., Garivait, S., & Wanthongchai, K. (2011). Carbon storage in above-ground biomass of tropical deciduous forest in Ratchaburi Province, Thailand. *World Academy of Science, Engineering and Technology*, 58, 636-641.
- Chingchai, W. (2003). A handbook for biomass estimation of tree communities. Bangkok: Department of National Parks, Wildlife, and Plant Conservation.
- Cunningham, A. B. (2014). Applied ethnobotany: people, wild plant use and conservation. Routledge.
- Curtis, J. T. (1959). The vegetation of Wisconsin: an ordination of plant communities. University of Wisconsin Press.
- Dar, J. A., Subashree, K., Raha, D., Kumar, A., Khare, P. K., & Khan, M. L. (2019). Tree diversity, biomass and carbon storage in sacred groves of Central India. *Environmental Science and Pollution Research*, 26(36), 37212-37227. <http://doi.org/10.1007/s11356-019-06854-9>
- Doffana, Z. D. (2017). Sacred natural sites, herbal medicine, medicinal plants and their conservation in Sidama, Ethiopia. *Cogent Food & Agriculture*, 3(1), 1365399. <http://doi.org/10.1080/23311932.2017.1365399>

- Garcia, H., & Miralles, F. (2020). Forest bathing: The rejuvenating practice of Shinrin Yoku. Tuttle Publishing.
- Gerique, A. (2006). An introduction to ethnoecology and ethnobotany: Theory and methods. Integrative assessment and planning methods for sustainable agroforestry in humid and semiarid regions. *Advanced Scientific Training* (Ed.), 20p. Loja, Ecuador.
- Hariyadi, S., & Madduppa, H. (2021). Diversity, density, and importance value index of mangroves in the Segara Anakan lagoon and its surrounding area, Cilacap Regency, Indonesia. In *IOP Conference Series: Earth and Environmental Science* (Vol. 744, No. 1, p. 012034). IOP Publishing. <http://doi.org/10.1088/1755-1315/744/1/012034>
- Keerthika, A., & Chavan, S. B. (2022). Oxygen production potential of trees in India. *Current Science*, 122(7), 850. <http://doi.org/10.18520/cs/v122/i7/850-853>
- Keith, H., Vardon, M., Obst, C., Young, V., Houghton, R. A., & Mackey, B. (2021). Evaluating nature-based solutions for climate mitigation and conservation requires comprehensive carbon accounting. *Science of the Total Environment*, 769, 144341. <http://doi.org/10.1016/j.scitotenv.2020.144341>
- Lowman, M. D., & Sinu, P. A. (2017). Can the spiritual values of forests inspire effective conservation? *BioScience*, 67(8), 688-690. <http://doi.org/10.1093/biosci/bix057>
- Manuri, S., Putra, C. A. S., & Saputra, A. D. (2011). Teknik pendugaan cadangan karbon hutan. Merang REDD Pilot Project, German International Cooperation-GIZ. Palembang.
- Maru, Y., Gebrekirstos, A., & Haile, G. (2023). Indigenous sacred forests as a tool for climate change mitigation: Lessons from Gedeo community, Southern Ethiopia. *Journal of Sustainable Forestry*, 42(3), 260-287. <http://doi.org/10.1080/10549811.2021.2007490>
- Mequanint, F., Wassie, A., Aynalem, S., Adgo, E., Nyssen, J., Frankl, A., ... & Strubbe, D. (2020). Biodiversity conservation in the sacred groves of north-west Ethiopia: Diversity and community structure of woody species. *Global Ecology and Conservation*, 24, e01377. <http://doi.org/10.1016/j.gecco.2020.e01377>
- Nolan, J. M., & Turner, N. J. (2011). Ethnobotany: The study of people-plant relationships. *Ethnobiology*, 9, 133-147. <http://doi.org/10.1002/9781118015872.ch9>
- Nowak, D. J., Hoehn, R., & Crane, D. E. (2007). Oxygen production by urban trees in the United States. *Arboriculture and Urban Forestry*, 33(3), 220. <http://doi.org/10.48044/jauf.2007.026>
- Oliveira, P. C. D., & Queiroz de Sou, B. C. D. O. (2020). Traditional knowledge of forest medicinal plants of munduruku indigenous people-ipaupixuna. *European Journal of Medicinal Plants*, 31(13), 20-35. <http://doi.org/10.9734/ejmp/2020/v31i1330309>
- Pandey, A. (2022). A literary analogy of the contributions of "Cultural Services" to the ecosystem services provided by the Sacred Groves. *Magna Scientia Advanced Research and Reviews*, 6(1), 008-030. <http://doi.org/10.30574/msarr.2022.6.1.0061>
- Ramanan, S. S., Arunachalam, A., Shanker, A. K., & Sridhar, K. B. (2022). Oxygen production potential of trees—unrealistic perception in India. *Current Science*, 123(8), 957. Roux, J. L., Konczal, A. A., Bernasconi, A., Bhagwat, S. A., De Vreese, R., Doimo, I., ... & Winkel, G. (2022). Exploring evolving spiritual values of forests in Europe and Asia: A transition hypothesis toward re-spiritualizing forests. *Ecology & Society*, 27(4), 1-20. <http://doi.org/10.5751/ES-13509-270420>
- Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., ... & Turner, B. (2021). Getting the message right on nature-based solutions to climate change. *Global Change Biology*, 27(8), 1518-1546. <http://doi.org/10.1111/gcb.15513>
- Shrestha, L. J., Devkota, M., & Sharma, B. K. (2020). Tree diversity conservation initiatives in sacred groves of Kathmandu Valley, Nepal. *Nepal Journal of Science and Technology (NJST)*, 19(1). <http://doi.org/10.3126/njst.v19i1.29768>
- Sprugel, D. G., Ryan, M. G., Brooks, J. R., Vogt, K. A., & Martin, T. A. (1995). Respiration from the organ level to the stand. In *Resource Physiology of Conifers* (pp. 255-299). Academic Press. <http://doi.org/10.1016/B978-0-08-092591-2.50013-3>
- Suthari, S., Kandagalta, R., Ragan, A., & Raju, V. S. (2016). Plant wealth of a sacred grove: Mallur Gutta, Telangana State, India. *International Journal of General Medicine*, 369-381. <http://doi.org/10.2147/IJGM.S83441>
- Tacconi, L., Moore, P. F., & Kaimowitz, D. (2007). Fires in tropical forests: What is really the problem? Lessons from Indonesia. *Mitigation and Adaptation Strategies for Global Change*, 12, 55-66. <http://doi.org/10.1007/s11027-006-9040-y>
- Teeuwen, M., & Scheid, B. (2002). Tracing Shinto in the history of Kami worship: Editors' introduction. *Japanese Journal of Religious Studies*, 29(3/4), 195-207.
- Tsutsumi, T., Yoda, K., Sahunalu, P., Dhanmanonda, P., & Prachaiyo, B. (1983). Forest Felling, Burning and Regeneration in Shifting Cultivation: An Experiment at Nam Phrom, Northeast Thailand and Its Implications for Upland Farming in the Monsoon Tropics. Bangkok.
- Vadrevu, K. P., Lasko, K., Giglio, L., Schroeder, W., Biswas, S., & Justice, C. (2019). Trends in vegetation fires in south and southeast Asian countries. *Scientific Reports*, 9(1), 7422. <http://doi.org/10.1038/s41598-019-43940-x>
- Wadley, R. L., & Colfer, C. J. P. (2004). Sacred forest, hunting, and conservation in West Kalimantan, Indonesia. *Human Ecology*, 32(3), 313-338. <http://doi.org/10.1023/B:HUEC.0000028084.30742.d0>
- World Health Organization. (2020). Health and climate change: Country profile 2020: Dominica (No. WHO/HEP/ECH/CCH/20.01.04). World Health Organization.
- Rots, A. P. (2014). *Forests of the Gods: Shinto, Nature, and Sacred Space in Contemporary Japan*. Routledge.

