Bamboo Knowledge, Ritual Regulation, and Biocultural Resilience: Technical Practices and Symbolic Meanings among the Ngadha of Flores, Indonesia

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Abstract

Background

Bamboo has long been recognized as a “thousand-use plant” that bridges subsistence, symbolism, and sustainability across societies. Yet little is known about how customary regulation sustains bamboo ecologies under modernization in eastern Indonesia.

Methods

We conducted multi-sited ethnographic research (2018–2021) in four Ngadha villages (Flores, Indonesia), combining participant observation, semi-structured interviews (n = 35), and focus group discussions. The study documented technical practices, proverbs (*pata dela*), and customary rituals (*ri’i*, ritualized harvesting prohibition; *waja*, ritual clump restoration).

Results

We recorded 54 uses of bamboo across eight domains: construction, household utensils, agriculture, hunting, games, music, ritual, and protective fencing. *Dendrocalamus asper* emerged as the cultural keystone species, sustaining both subsistence and symbolic functions. Domestic uses have declined due to plastics, concrete, and corrugated iron, but bamboo endures in ritual, musical, and symbolic domains, demonstrating biocultural resilience. Comparative analysis with Asia, Africa, and the Pacific highlights the distinctiveness of Ngadha’s ritualized conservation as a formalized ecological governance system.

Conclusions

The Ngadha case contributes theoretically to debates on Traditional Ecological Knowledge (TEK), enskilment, and the material culture of continuity, while practically informing policy experiments such as the *Hutan Bambu Lestari* (HBL, Sustainable Bamboo Forest program), an initiative led by *Yayasan Bambu Lestari* (YBL, Bamboo Foundation). TEK in this context is not static but adaptive, offering a culturally grounded model for global biocultural conservation.

1. Introduction

Bamboo is often described as the “thousand-use plant,” a resource that bridges subsistence, symbolism, and sustainability across many societies [1]. Among the Ngadha of Flores, Indonesia, bamboo occupies a central place not only in material culture but also in the cosmological order. Customary rituals such as *ri’i* (harvest prohibition) and *waja* (clump restoration) regulate its use while safeguarding ecological continuity. Local proverbs likewise situate bamboo as a moral compass: *bhêto took wolo, go ura da malo bholo* (“a small bamboo on the hillside remains strong”) and *moe sa’a bhêto ngia lêbê* (“like climbing while carrying bamboo”) convey lessons of resilience and perseverance. Bamboo thus stands not only as a material resource but also as an ethical guide woven into everyday life.

The convergence of material, moral, and ecological dimensions has consistently attracted interdisciplinary scholarly interest. Recent studies underline bamboo’s strategic role within global sustainability agendas, with research highlighting its significance for climate change mitigation, soil conservation, and rural livelihoods [2]. Its potential as a disaster-resistant construction material has also been emphasized [3], while its use in climate-responsive architecture

in Arunachal Pradesh illustrates its adaptive possibilities in design [4]. At the same time, scholarship points to the frictions between tradition and modernity: urbanization in Assam has reshaped bamboo's cultural value [5], and traditional craftsmanship in Bangladesh faces mounting pressure under market competition [6]. These comparative perspectives provide critical context, yet the Ngadha case is distinctive in the way *ri'i* and *waja* serve as formalized mechanisms that intertwine ecological conservation with cosmological legitimacy.

Classic ethnobiological research has long underscored that bamboo is never solely utilitarian. Early surveys across Asia revealed its dual role as both a material resource and a spiritual symbol [7]. Similar insights emerged from the Pacific, where bamboo among the Awa people was shown to shape not only subsistence technologies but also symbolic practices [8]. Such accounts highlight that human–bamboo relations extend beyond technical functions and are deeply embedded in cultural meanings and moral significance.

In the Indonesian context, bamboo has been identified as a cultural keystone species that simultaneously anchors subsistence, ecology, and symbolism [9]. The Ngadha experience thus resonates with broader Indigenous traditions across the archipelago. Beyond Indonesia, studies further illuminate bamboo's ecological and cultural salience: among the Mao-Naga of Northeast India, folk taxonomies inform soil conservation and seasonal knowledge [10]; in Yunnan, participatory documentation has been advocated to safeguard bamboo-related Traditional Ecological Knowledge [11]; and in Nepal, traditional practices have persisted despite modernization pressures [12]. Collectively, these works situate Ngadha within a wider global constellation of biocultural practice.

Although scholarship on TEK has long stressed the adaptive nature of local practices [13], detailed ethnographic accounts remain necessary—especially in communities now confronted by modernization, migration, and industrial markets. Without such documentation, the material and symbolic dimensions of bamboo risk being erased by the homogenizing currents of modern life.

This article is framed by two theoretical perspectives. First, the concept of biocultural diversity [13], which emphasizes the interconnections among ecological knowledge, language, and social relations. This framework allows us to see bamboo not simply as a plant but as a nexus linking ecology, culture, and identity. Second, the dwelling perspective emphasizes that knowledge is generated through lived engagement, shaped by ongoing interactions with landscapes, materials, and social rhythms [14]. From this view, Ngadha technical knowledge of bamboo—age classification, site selection, harvesting methods—cannot be separated from the cosmologies, ethics, and collective memories in which it is embedded.

Against this backdrop, the aim of this article is to document, ethnographically, the technical knowledge, philosophical meanings, and transformations of bamboo practice among the Ngadha. We highlight how local skills—classifying culms by age, selecting growth sites, timing harvests—are interwoven with symbolic values and customary regulations, reinforcing both collective identity and ecological sustainability. Drawing on fieldwork (2018–2021) and comparative global literature, the article contributes to ongoing debates on the dynamics of biocultural knowledge and their implications for sustainable landscape governance.

2. Methods

This study employed an ethnographic approach to document the technical knowledge, symbolic meanings, and shifting practices of bamboo use among the Ngadha of Flores. Ethnography is understood here not merely as a data collection technique but as an interpretive framework that enables the researcher to grasp social practices from the actors' own perspectives [15].

Fieldwork was conducted intermittently between 2018 and 2021 across four villages in Ngada Regency that continue to maintain strong traditions of bamboo use in both domestic and ritual life. These sites were purposively selected to capture variations across social spaces: the traditional house (*sa'o*), bamboo gardens and groves, and ordinary households that have increasingly adopted modern materials.

A total of 35 primary informants participated in the study, including customary elders, bamboo artisans, farmers, traditional musicians, and young people. Informants were recruited through snowball sampling, beginning with village heads and customary leaders who then introduced the researcher to other families and individuals with bamboo-related skills [16]. Semi-structured interviews were conducted around five thematic areas: (1) local bamboo classification (names, characteristics, selection criteria); (2) harvesting and processing techniques; (3) domestic and ritual applications; (4) proverbs and philosophical meanings; and (5) perceptions of change under modernization. In addition to individual interviews, focus group discussions (FGDs) were held in each village with mixed participants—ordinary residents, artisans, youth/Catholic youth groups (Organisasi Muda Katolik, OMK), and some customary leaders—to validate findings, map intergenerational shifts, and gauge consensus or disagreement regarding *ri'i–waja* regulations and harvesting practices.

Participant observation was also carried out in everyday activities such as bamboo harvesting, household tool-making, *sa'o* construction, and ritual celebrations involving bamboo instruments. Visual documentation (photographs) was undertaken with permission from participants and customary authorities, primarily to capture processes (e.g., cutting techniques, culm selection, assembly of *naja* and *lat*). An inventory of bamboo artifacts was compiled in tabular form, noting local names, functions, culm parts used, species, and contexts of use. All tables (except where noted otherwise) and figures/photographs are based on the author's field data (2018–2021). Data validity was ensured through source triangulation (cross-checking among informants), FGDs across social roles, and comparison with the literature. Interview transcripts and fieldnotes were analyzed using an inductive–deductive thematic approach, linking technical categories (e.g., culm age, culm parts, harvesting seasons) with symbolic categories (*pata dela*, cosmology, customary norms).

The research adopted a multi-sited design, tracing bamboo's roles across domestic, public, and ecological spaces, thereby revealing its functions from practical uses to cosmological symbolism [17].

Ethically, the study followed local norms and principles of informed consent: interviews, photographs, and observations were conducted only with community approval, personal identities were anonymized, and photographs were used with explicit permission, while customary restrictions such as ritual entry protocols were respected [18].

To strengthen methodological rigor, the study explicitly considered the reflexive position of the researcher. Snowball sampling and participant observation are not neutral techniques but are shaped by the positionality of the researcher [16]. In this case, access to informants and interpretation of meanings were influenced by the author's dual role as insider—familiar with Indonesian ethnographic contexts—and outsider—not a member of Ngadha society—which required ongoing negotiation of trust and transparency. Data analysis employed an inductive–deductive thematic approach, drawing on traditions of open and axial coding in qualitative research [19]. This iterative process linked technical categories such as culm age and harvesting techniques with symbolic categories such as proverbs, cosmology, and customary norms, thereby ensuring that the analysis remained grounded in emic perspectives while engaging broader theoretical frameworks [20].

Terminology and Orthography Note

In this article, *Ngada* (without "h") refers to the administrative district on Flores Island, whereas *Ngadha* (with "h") designates the ethnic group inhabiting the area. The Ngadha language distinguishes two variants of the vowel *e*: the

mid-front vowel /e/ (as in Indonesian *bebek*), and the schwa /ə/ (*e pepet*, as in *penuh*). To reflect these distinctions, the schwa is represented here with the diacritic "ê." This orthographic convention is applied consistently throughout proverbs (*pata dela*) and local terminologies to maintain linguistic accuracy and respect for emic expressions.

3. Results

3.1. Philosophical Meanings & *Pata Dela*

For the Ngadha people, bamboo is not only regarded as a versatile material but also as a moral symbol, a spiritual medium, and a marker of collective identity. These values are transmitted orally through *pata dela* (proverbial expressions), which serve as ethical guidelines and reflections on human–nature relations. In this sense, bamboo is present not only in its material form but also as a vehicle of moral and spiritual education that binds the community across generations. Beyond its educational role, *pata dela* also acts as a "bridge" between cosmological norms and technical practices (see Results: Customary regulation), since moral teachings such as resilience, social order, and discretion underpin adherence to harvesting rules and clump restoration rituals.

An inventory of local proverbs reveals that the philosophical meanings of bamboo among the Ngadha can be grouped into four main themes, with two additional sub-themes that highlight its relevance to social order and the transmission of values. Resilience is conveyed in the saying *bhêto took wolo, go ura da malo bholo* ("though small, must remain strong"), which teaches the importance of perseverance despite humble origins. This philosophy is reinforced by the growth cycle of bamboo: during its first five years, roots penetrate deeply into the soil before the culm rises tall, a metaphor for patience and endurance as prerequisites for success. Secrecy appears in the proverb *moe wae satu bhêto* ("water inside bamboo"), which symbolizes hidden thoughts or inner feelings and emphasizes the need for discretion and wisdom in speech. Honesty is reflected in the saying *moe bhêto rogho olo, bei wara langa*, which criticizes those who judge others' faults while ignoring their own, thereby promoting honesty, self-reflection, and fairness in social life. Leadership is articulated in the proverb *bhêto tolo woso, ladho dhomi se take* ("one clump shelters many people"), framing bamboo as a metaphor for just, protective, and responsible leadership—underscoring the duty of leaders to safeguard their community, much like a clump of bamboo shades its surroundings. Two additional sub-themes enrich this symbolic repertoire. Social order is emphasized in the saying *ge nua ne'e fa;o bhêto ngata* ("each village has its bamboo grove"), which asserts that every community has its own law and authority, echoing the logic of bamboo clump management and rights of access. Finally, inheritance and kinship are conveyed in the expression *moe foka duku rapu* ("each shoot follows the clump"), which stresses the intergenerational transmission of character and skills, explaining why bamboo enskilment is passed down together with moral discipline as a unified package.

Comparative perspectives show that the symbolic meanings of bamboo in Ngadha echo broader traditions: in Confucian thought, bamboo embodies steadfastness and humility [21–23]; among the Apatani in India, it serves as both an agrarian resource and a moral foundation for collective governance [24, 25]; and more broadly, it has been described as a "material culture of continuity," sustaining socio-ecological resilience across generations [26]. In Ngadha, these resonances appear not only at the level of meaning but also in practice: *pata dela* provides an "ethical language" that legitimizes technical practices (e.g., culm selection, cautious knowledge-sharing) and ensures compliance with customary mechanisms such as *ri'i* and *waja*.

Thus, *pata dela* is not merely entertaining folklore but a moral–ecological framework that regulates behavior, strengthens solidarity, and affirms the collective identity of the Ngadha. The symbolism of bamboo bridges practical and philosophical dimensions, making it inseparable from the cultural ecology of the community. To maintain focus on

the central argument, a more extensive corpus of over twenty *pata dela* is presented in Additional file 1, while Table 1 below highlights representative examples across the themes.

Table 1
Representative Ngadha proverbs (*pata dela*) by thematic category.

Theme	Proverb (Ngadha)	Literal Translation	Interpretation
Resilience	*bhêto took wolo, go ura da malo bholo*	"Though small, must remain strong"	Strength and perseverance despite humble origins
	moe sa'a bhêto ngia lêbê	"Like carrying bamboo while climbing"	Challenges requiring patience and persistence
Secrecy	*moe wae satu bhêto*	"Water inside bamboo"	Hidden thoughts; discretion in communication
	moe sobe sêsi bha'i	"Bamboo water without a stopper"	Warning against indiscretion
Honesty	*moe bhêto rogho olo, bei wara langa*	"Like bamboo scratching others, yet ignoring its own"	Critique of hypocrisy; need for self-reflection
Leadership	*bhêto tolo woso, ladho dhomi se take*	"One clump shelters many people"	Ideal leadership: fair, protective, responsible
	bhêto ladho toko tau fao mala wolo	"A bamboo clump shades the entire hillside"	Leadership that provides collective protection
Social order	ge nua ne'e fa;o *bhêto ngata*	"Each village has a bamboo grove"	Local jurisdiction; each community has its own law/custom
Inheritance /kinship	moe foka duku rapu	"Each bamboo shoot follows the nature of the clump"	Intergenerational transmission of character/skills (enskilment)

Table 1 illustrates the diversity of *pata dela* employed by the Ngadha to instill moral values while simultaneously reflecting human–environment relations. The theme of resilience emphasizes perseverance in facing hardship; secrecy highlights the wisdom of discretion; honesty teaches self-reflection and critique of hypocrisy; while leadership positions bamboo as the model of ideal, protective authority. The sub-theme of social order links proverbs to the sovereignty of village customary law, whereas inheritance/kinship underscores the intergenerational transmission of character and skills. In this way, *pata dela* transcends the status of folklore and becomes a moral–ecological framework aligned with bamboo symbolism in other cultural traditions.

3.2. Technical Knowledge & Customary Regulation

Ngadha bamboo knowledge demonstrates a high degree of ecological systematization that may be described as *indigenous ecological science*. Rather than ad hoc practices, bamboo management is grounded in detailed classification, careful ecological observation, and binding customary rules. For the Ngadha, bamboo is not merely raw material but a living resource that must be treated with great care.

One important aspect is age-based classification. Local terminology distinguishes *a siza* (young, ± 1 year), typically used in rituals or to make simple containers due to its pliability; *hêto waza* (semi-mature), suitable for everyday tools such as household implements; and *azi esa* (mature), considered strongest and most flexible, ideal for house construction or hunting equipment. This classification is not only technical but also normative, since each growth stage is believed to carry its own "soul" and intended purpose. It illustrates how local ecological knowledge links plant age with material properties and uses, while also reflecting situational learning transmitted across generations.

Harvesting techniques are equally strict. Bamboo is cut during the dark moon phase, when moisture content is believed to be lowest, ensuring durability and resistance to pests. Culms are cut 10–15 cm above ground level—not at the root—to protect emerging shoots and support clump regeneration. Informants emphasized that culms from overcrowded or unhealthy clumps are prone to cracking, so clump health must be assessed prior to harvesting. Selection is also highly specific: culms from upland sites are preferred for musical instruments due to their clearer resonance, whereas thicker-walled lowland culms are used for construction (see Additional file 2 for a detailed inventory of functional uses). Figure 1 shows a Ngadha farmer harvesting bamboo using a traditional technique: cutting at a slanted angle just above the ground to protect new shoots, while selecting culms based on age and clump vitality.

Beyond technical practice, bamboo management is embedded in customary regulation. Two key rituals are *ri'i* and *waja*. *Ri'i* is a harvesting prohibition imposed until a designated time, marked by *tada* (a visible sign tied to young culms) placed at the clump. Violations are believed not only to breach adat but also to invite misfortune—from poor harvests to family calamities. *Waja* is a ritual of clump restoration, performed after major harvests or when clumps weaken, involving prayer, offerings, and acts of purification. These practices are not merely religious rites but mechanisms of ecological conservation, binding harvesting techniques to moral community obligations.

Such practices resonate with findings elsewhere. In Yunnan, China, the importance of participatory documentation of local bamboo knowledge has been highlighted, demonstrating the ecological and methodological relevance of age-based classification and harvesting practices [11]. Similarly, [2], reviewing Asia and Africa, highlighted that community-based bamboo management—especially when embedded in social norms—often underpins ecological sustainability, though its effectiveness depends heavily on intergenerational transmission and youth compliance.

In Ngadha, technical and normative dimensions of bamboo management form an inseparable whole. Skills of selection, classification, and harvesting are fused with sacred regulation, creating a management system that is not only materially efficient but also ecologically ethical. This demonstrates how local science and customary rules operate together as the foundation of biocultural sustainability.

3.3. Diversity of Utilization

Fieldwork inventory documented at least 54 types of tools, containers, musical instruments, ritual implements, and architectural structures made from bamboo. These artifacts can be grouped into eight major categories: house construction, household utensils, agriculture, hunting, traditional games, music, ritual, and protective fencing. The inventory highlights how bamboo functions as a versatile resource and backbone of everyday life among the Ngadha. For clarity, local terminology is as follows: *bhêto* = *betung* (*Dendrocalamus asper*), *ila* = *ampel* (*Bambusa vulgaris*), and *peri* = *ater* (*Gigantochloa ater*).

Analysis of Table 2 shows the dominance of *Dendrocalamus asper* (*bhêto/betung*) as the primary species underpinning nearly all functional categories. From the construction of *sa'o* houses, food containers, agricultural tools, and hunting weapons, to musical instruments, this species serves as the cultural backbone of Ngadha material life. Its ubiquity affirms its status as a cultural keystone species—one whose presence is essential for sustaining community subsistence, symbolism, and identity.

Two other species serve more specialized roles. *Bambusa vulgaris* (*ila/ampel*) is chosen for fine craftwork and lightweight containers such as woven bags (*lêga guru, kêpen*) or small instruments, prized for its pliability and ease of shaping. *Gigantochloa ater* (*peri/ater*), by contrast, is used for chicken fencing (*subi*), traditional games (*sagu alu*), and certain crafts requiring structural strength. Together, these species demonstrate a functional specialization, with *D. asper* dominating but complemented by the contributions of *B. vulgaris* and *G. ater*.

This diversity reflects the flexibility of Ngadha TEK. Species selection, culm section, and culm age are never random but follow a contextual ecological logic. The basal part of the culm is typically used for posts and fences, the middle for household utensils, and the upper section for musical instruments. Ritual implements such as *tibo* (divination/ritual device) are crafted from specially chosen culms. This distribution underscores that Ngadha TEK is not ad hoc practice but an adaptive, dynamic ecological knowledge system that integrates technical know-how with broader emic values.

Table 2
Bamboo uses in Ngadha by species and major functions.

Species (Latin & Local)	Construction	Household utensils	Agriculture	Hunting	Games	Music	Protective fencing
Dendrocalamus asper (*bhêto /betung*)	*Sa'o* house frames; *baru lenga* walls; granary posts (*tubo*), roof frames (*lenga*), wall panels (*naja*), binding straps (*lat*)	*Tuku hui* (meat container), *zezo* (sifter), *tuku leko* (grain storage), *maki po'o* (cooking vessel), *fego* (rice paddle), *zoi ngi'i* (toothpick)	*Zo'a* (dibble stick), *keke* (rice cutter), *ebha* (winnowing fan)	*Zupi* (blowpipe), *laja ngeta* (spear shaft), *le'e* (bow)	*Lengitana* (bamboo cannon), *sagu alu* (jumping game)	*Foy doa* (double flute), *foy pay*, *sowito*, *tobho*, *teko reko*	*Hala* (field fence), *folo* (house fence)
Bambusa vulgaris (*ila/ampel*)	Light house parts	*Lêga guru*, *kêpen* (woven bags), *tuku si'e* (salt), *tuku koro* (chili)	–	–	–	Small rattles	*Sala* (temporary fencing)
Gigantochloa ater (*peri/ater*)	–	Fine basketry, small containers	–	–	–	–	Chicken fence (*subi*)
Other minor species (local types)	Temporary huts (*dhoka*)	*Kodo manu* (chicken carrier), small containers	*Su'a bhêto* (weeder)	*Gala* (metal-tipped spear), *ghate* (animal trap)	*Topo*, *bedi* (martial games)	*Laba dera*, *laba toka*	–

As a summary, Table 2 outlines the major bamboo species and their associated functions. The complete technical inventory (54 entries)—including categories, local names (bhêto/*ila*/*peri*), Indonesian–English equivalents, functions, species, and culm parts used—is provided in Additional file 2. Together, this corpus illustrates both the breadth of technical practices sustaining daily life and the biocultural value of bamboo in Ngadha.

House construction.

Bamboo is central in building *sa'o* (ancestral houses), bamboo dwellings (*baru lenga*), and granaries. A medium-sized *sa'o* requires approximately 300 culms, with major components including *tubo* (posts), *naja* (split bamboo wall

panels), *lenga* (roof framework), and *lat* (binding straps). High-quality *naja* can last up to 70 years, while *lenga* typically needs replacement every three years due to weather exposure.

Figure 2 shows the main structural components of a traditional bamboo house—*lenga*, *lat*, *naja*, and *tubo*—illustrating how each culm section serves a specific architectural role.

As shown in Fig. 3, the processed bamboo panels (*naja*), strips (*lat*), and posts (*tubo*) are assembled into the walls of a Ngadha *sa'o*, reflecting a design that balances durability with flexibility.

The roofing system, presented in Fig. 4, demonstrates the application of *lenga* in both the interior framework and the exterior pattern of the bamboo roof, embodying local principles of renewal and ecological continuity.

Together, these figures illustrate how culms are selected, processed, and renewed periodically—enabling houses to last for decades without severing their ecological and cultural foundations.

Household utensils.

Bamboo is indispensable in kitchens and households. Examples include *tuku hui* (pork container, Fig. 5), *zezo* (sifter for maize), *tuku leko* (grain container), *tuku si'e* (salt container), *tuku koro* (chili container), *kodo manu* (chicken carrier), *maki po'o* (vessel for sticky rice), and *rodho* (steamer). Simple tools such as *fego* (rice paddle) and *zoi ngi'i* (toothpick) demonstrate bamboo's ubiquity in daily domestic life. The *tuku hui* is particularly illustrative: its porous culm structure keeps meat fresh for extended periods, functioning as a "natural refrigerator" within local food logic.

Agriculture.

Agricultural implements include *zo'a* (dibble stick), *su'a bhêto* (weeder), *keke* (rice-harvesting tool), and *ebha* (winnowing fan). Temporary field huts (*dhoka*) are also constructed from bamboo frames.

Hunting.

Bamboo supports household protein subsistence through hunting. Implements include *laja ngeta* (spear), *le'e* (bow), *zupi* (blowpipe), *gala* (iron-tipped spear), and traps such as *ghate* for wild pigs and deer. Culm selection is specific: denser-fibered culms are used for weapons, while straight, evenly hollow culms are chosen for blowpipes.

Games.

Children's and youth games also rely on bamboo. *Lengitana* (bamboo cannon) is played at New Year, *sagu alu* (bamboo jumping dance) trains rhythm and coordination, while *topo* and *bedi* serve as mock martial games. Informants noted that such games are now rarely practiced, as the skills are transmitted orally and are declining with younger generations.

Music.

Bamboo musical instruments play vital roles in rituals. These include *foy doa* (double flute) and *foy pay* (Fig. 6), as well as *sowito, tobho, teko reko, laba dera*, and *laba toka*. Culms from upland areas are preferred for instruments because of lower moisture content, producing clearer tones. These instruments are not only aesthetic but also cosmological: their sounds are believed to mediate between humans and ancestral spirits.

Protective fencing.

Bamboo is used for fences such as *hala/sala* (field/pig pen fences), *subi* (chicken fence), and *folo* (house fence). Construction techniques vary, ranging from vertical weaving to horizontal stacking.

Ritual implements.

Beyond domestic and subsistence roles, bamboo also plays a central role in ritual. The *tibo* ritual, used to seek ancestral guidance prior to major decisions, relies on symbolic media such as *kili nio* (fresh coconut), *mau tua* (palm toddy), and *leba tibo* (a bamboo segment consisting of two nodes and three internodes, as shown in Fig. 7). Unlike other media, *leba tibo* holds a special role: it is used not only in everyday customary consultations but also in the *ri'i* ceremony, particularly to determine who should lead the ritual, when it should be held, and where it should take place. In this sense, bamboo in the form of *leba tibo* affirms its dual role as both a material and a spiritual medium, anchoring ancestral communication in processes of customary decision-making.

Beyond its utilitarian value, informants often referred to bamboo as a "companion" and "guardian of the household," reflecting both emotional attachment and ecological dependence where practical functions are inseparable from symbolic significance. Bamboo is thus perceived not merely as an object but as an active agent in sustaining household and community balance. Comparable observations emerge elsewhere: in Northeast India, over 30 bamboo varieties have been recorded for uses spanning food, construction, and ritual [27], while in Nepal, multifunctional bamboo traditions persist despite modernization pressures [12]. Taken together, these parallels situate Ngadha bamboo practices within a wider global pattern of biocultural adaptation.

3.4. Social Transformation

Modernization has brought profound consequences for patterns of bamboo use in Ngadha. Whereas in the past bamboo was the dominant material for nearly all aspects of daily life—from houses and kitchen utensils to children's games—it has gradually been displaced by industrial materials considered more practical and prestigious. Bamboo houses are now increasingly rare, with many families turning to brick walls and corrugated metal roofs. Domestic bamboo utensils such as *tuku hui*, *zezo*, and *tuku leko* have largely been replaced by plastic or metal containers easily obtained in the market. These changes have been most rapid in the domestic sphere, while the ritual domain has remained relatively stable due to its enduring cosmological significance (see Section 3.1).

Figure 8 illustrates the striking contrast between a *sa'o* with bamboo/thatched roofing and a modern house with a corrugated metal roof. If the *sa'o* represents cosmological continuity through bamboo materials, the metal roof signals aspirations for modernity and new social status. This shift demonstrates how material culture embodies the transformation of values and community preferences.

Changes are also evident in the frequency and modes of accessing bamboo. Informants noted that the installation of *tada* (markers indicating harvest prohibitions under *ri'i*) has become increasingly rare, and bamboo extraction is now more often conducted individually rather than through *nua/woe* (clan or hamlet councils). In some cases, families even purchase bamboo from outside the village when local supplies run low—an indication of both commercialization and the weakening of communal reserves. The relocation of settlements to roadside areas in recent decades has facilitated market access but has also distanced households from their ancestral groves, leading to reduced care for traditional bamboo stands.

Amid these shifts, technical responses have emerged to counter the pace of degradation. Community programs such as HBL, an initiative of YBL, have introduced sustainable harvesting practices through clump tagging with harvest codes, bamboo field schools, and household nurseries. These efforts align with ecological sustainability principles long recognized locally (see Section 3.2), though their basis of legitimacy differs: technical procedures replace ritual

authority. Adoption has also been uneven, with younger generations and roadside households more readily embracing technical innovations compared to families still oriented around the *sa'o*.

Taken together, these transformations highlight the dynamics of biocultural resilience: modernization encourages the adoption of new materials for comfort and prestige, yet bamboo persists in ritual and symbolic domains as a marker of identity and communal morality. This pattern resonates with reports from other parts of Asia, where bamboo's multifunctionality is retained but renegotiated under the pressures of markets and modern materials. A theoretical elaboration on the "disenchantment" of customary regulation and the disembedding of communal practices is developed further in the Discussion.

4. Discussion

4.1. Continuity and Change

In the past, bamboo in Ngadha life was often described as a "thousand-use plant," sustaining nearly every aspect of daily existence—from house construction and kitchen utensils to farming and children's games. Ethnographic inventories reveal the breadth of these uses. Yet, modernization and the penetration of industrial materials have reshaped this material landscape. Today, most domestic functions of bamboo are gradually replaced by other materials, while its roles in ritual, music, and symbolism remain resilient.

Continuity is most evident in ritual and symbolic domains. The practices of *ri'i* and *waja* (see Section 3.2) are still carried out in several villages as customary mechanisms that link bamboo to ancestral cosmology while also ensuring ecological conservation. In *ri'i*, bamboo clumps are ritually marked with offerings of chicken or pig, making violations symbolically dangerous and believed to invite misfortune. The traditional *sa'o* house—with bamboo and thatch roofing—remains preserved as a ritual center, even as modern brick-and-metal-roof houses proliferate nearby. Likewise, bamboo music such as *foy doa*, *foy pay*, *sowito*, and *tobho* continues to be performed during rituals and collective celebrations, strengthening social ties and transmitting tradition across generations. Instruments like the *foy doa* (double flute) are played not only for entertainment but also as ethical media, expressing values of solidarity and leadership. Local proverbs such as *bheto took wolo, go ura da malo bholo* ("a small bamboo growing on the hillside remains strong") or *bheto ladho toko tau fao mala wolo* ("a bamboo clump shades the entire hill") highlight bamboo as a symbol of resilience, solidarity, and just leadership. These align with the idea of bamboo as a "material culture of continuity"—a medium that binds generations through practice and symbolism [26].

By contrast, change is most visible in the domestic sphere. Household items such as *tuku hui*, *zezo*, or *rodho* are now rarely used, replaced by plastic and metal containers that are more durable and readily available in markets. Bamboo houses (*baru lenga*) have also become scarce, replaced by brick walls and corrugated roofs seen as both more durable and socially prestigious.

Statistical data reinforce these ethnographic observations. Population census figures from the Central Bureau of Statistics (BPS) show a sharp decline in bamboo-walled houses across Ngada Regency. Between 2018 and 2023, bamboo houses fell from 3,812 units (14.2%) to 2,196 units (7.9%). In contrast, brick houses increased substantially—from 22,995 units (85.8%) in 2018 to 25,449 units (92.1%) in 2023. Expressed in proportional terms, brick/concrete-walled houses rose from 60.5% to 68.3% of all dwellings, while bamboo houses dropped from 11.2% to just 8.3% during the same period [28].

A similar trend is visible at the sub-district level in Golewa, one of the study sites: bamboo houses decreased from 1,254 (12.1%) in 2018 to just 680 (6.2%) in 2023, while brick houses rose from 9,089 (87.9%) to 10,295 (93.8%) during

the same period. In proportional terms, the decline was even sharper, with bamboo houses falling from 8.6% to only 5.1% of households in five years, while brick dwellings expanded to nearly 94% [28].

These quantitative changes are summarized in Table 3, which compares the transition in housing materials between Ngada and Golewa from 2018 to 2023. The table clearly shows the downward trend in bamboo houses and the parallel rise in brick or concrete structures, reinforcing the ethnographic finding that bamboo is increasingly marginalized in domestic life.

Table 3
Housing transition in Ngada and Golewa, 2018–2023.

Year	Bamboo houses (Ngada)	%	Brick houses (Ngada)	%	Bamboo houses (Golewa)	%	Brick houses (Golewa)	%
2018	3812	14.2	22995	85.8	1254	12.1	9089	87.9
2023	2196	7.9	25449	92.1	680	6.2	10295	93.8

Source: BPS Ngada (2019–2024).

These statistics confirm a rapid material transition, aligning with field observations that bamboo houses are increasingly abandoned for modern brick-and-metal structures. More than just a technical substitution, this shift reflects new aspirations for comfort, durability, and prestige. At the same time, the decline of bamboo architecture underscores a broader weakening of bamboo-based domestic knowledge, as skills in processing and maintaining bamboo walls (*naja*) or roofing (*lenga*) are no longer widely transmitted.

Children's games once made of bamboo, such as *lengitana* (bamboo cannon) or *topo* (toy machetes), have nearly disappeared, as the skills to make them are no longer actively transmitted and children now prefer modern games.

This pattern illustrates a divergence between "pragmatic adaptation" and "ritual conservation." In domestic life, people pragmatically adopt new materials that are more durable, practical, and prestigious. In ritual and symbolic realms, however, resistance to change prevails: bamboo remains the key medium for upholding customary norms, maintaining cosmology, and affirming collective identity. Yet, knowledge transmission faces challenges. Focus group discussions (FGDs) revealed that younger generations are less engaged in bamboo crafts or clump management, partly due to inheritance rules and parental authority. Even so, OMK provide new spaces for transmitting bamboo skills. Thus, continuity and change are not contradictory, but rather two parallel pathways of adaptation—one oriented toward practical efficiency, the other toward cultural and ecological conservation.

Comparative studies reinforce this pattern. In China, bamboo continues to symbolize Confucian values of resilience and humility even as its material functions are replaced [21–23]. Among the Apatani in Northeast India, bamboo is preserved in agrarian rituals despite domestic functions shifting to modern materials [24, 25]. In Benin, bamboo retains high utility but is increasingly displaced by industrial timber and imported material [29]. In the Pacific, the Awa community emphasizes bamboo's symbolic dimension, which endures longer than its technical functions [8]. These cases confirm that Ngadha's experience is part of a broader global dynamic, where "biocultural resilience" allows ritual and symbolism to persist longer than pragmatic functions.

The Indonesian context shows similar patterns. In Kalimantan, bamboo in *simpukng* Dayak agroforestry systems is managed through customary inheritance across generations [30]. In Sumedang, West Java, taboos remain in force, such as prohibitions against felling bamboo on Fridays or the ritual use of certain species as protective charms [31].

On Weh Island, eight bamboo species are recorded for food, medicine, construction, and children's games [32], reflecting a range of uses comparable to Ngadha.

Market pressures and industrialization are also evident. In Ngada, the shift from community-based bamboo use to integration into industrial supply chains is hampered by limited managerial capacity, despite strong social capital [33]. In Nepal, incorporating TEK into modern bamboo supply chains faces similar hurdles [34]. In Vietnam, wild bamboo risks commodification if equitable governance is not applied [35]. Ethnographic evidence from Ngadha (2018–2021) also suggests that *ri'i* has weakened under the forces of modernization, individualization, and commodification, with bamboo increasingly treated as a market commodity, although some communities experiment with simplified rituals or conservation-oriented adaptations.

Finally, the biocultural and spiritual dimensions strengthen the case for continuity. In Sumba, the Marapu belief system safeguards bamboo and water sources through sacred prohibitions—paralleling *ri'i* in Ngadha [36]. In Karangwangi, West Java, bamboo is even described as a "cultural keystone species," embedded in language, narratives, and ritual [9].

4.2. Comparative Insights

Global studies broaden the scope of this argument. Bamboo has been shown to contribute to all forms of livelihood capital—natural, social, economic, and cultural—even though research remains heavily Asia-focused [2]. Beyond livelihoods, bamboo also plays a key role in biodiversity conservation, carbon sequestration, and global ecosystem services [37]. The Ngadha case should therefore be understood not merely as a local resource system, but as part of a wider dynamic in which bamboo is a central component of global sustainability discourses.

Theoretical frameworks also illuminate these findings. The concept of TEK emphasizes that cultural adaptation does not erase traditional knowledge but filters functions that remain ecologically and symbolically relevant [13]. Ingold's dwelling perspective highlights how human engagement with materials and landscapes is continuously negotiated: bamboo may be abandoned in domestic practices but remains vital in rituals that reaffirm cosmological relations [14]. The duality of continuity and change in Ngadha bamboo use thus demonstrates that local knowledge is a dynamic system, balancing pragmatic efficiency with symbolic conservation to sustain biocultural resilience.

Comparative cases show that bamboo use in Ngadha resonates with practices across Asia, Africa, and the Pacific. In Asia, studies among the Apatani of India highlight bamboo's persistence in agrarian rituals despite its declining role in household functions [24]. This parallels Ngadha, where bamboo no longer dominates domestic utensils but remains central to rituals such as *ri'i* and *waja* (see Section 3.2). In China, bamboo's symbolic role within Confucian traditions remains strong [7, 21–23], mirroring Ngadha proverbs such as *bhêto ladho toko tau fao mala wolo* ("a bamboo clump shades the entire hill"), which frame bamboo as a model of just leadership and communal protection. Similarly, [11] document in Yunnan a folk taxonomy of bamboo based on age, growing location, and usage function—closely resonating with Ngadha techniques of assessing bamboo by age categories (*a siza*, *azi esa*) and harvesting during the dark moon phase to ensure regeneration (see Section 3.2).

In Africa, research in Benin has shown that bamboo retains considerable utility in construction and handicrafts, yet it is increasingly displaced by industrial timber and imported materials [29]. This pattern resonates with the Ngadha case, where bamboo is similarly marginalized by concrete, zinc, and plastic, while continuing to endure in ritual and symbolic domains. However, unlike Benin—where no formal customary regulations exist—Ngadha practices exhibit *ritualized conservation* through mechanisms such as *ri'i* and *waja* (see Section 3.2), underscoring a distinctive transformation in which bamboo is not merely a practical resource but an object of institutionalized cosmological governance.

In the Pacific, bamboo has been described as serving primarily as a moral and identity symbol rather than as a technical material, particularly among the Awa people [8]. This observation reinforces a broader global pattern in which bamboo continues to endure within symbolic and moral domains, even as its practical applications are increasingly supplanted by modern materials.

From the Philippines, ethnographic research among the Pala'wan in Palawan demonstrates that bamboo is embedded not only in everyday practices but also in coastal ecological knowledge and community identity [38]. In mangrove areas, bamboo functions simultaneously as a utilitarian resource and a symbolic medium, linking human adaptation with fragile coastal ecosystems. This case resonates with Ngadha, where bamboo persists in ritual and symbolic domains despite pressures of modernization, thereby extending the scope of biocultural resilience across upland and coastal Southeast Asia.

Two broad insights emerge from these comparisons. First, the similarity: across Asia, Africa, and the Pacific, bamboo is maintained as a key element of collective identity, moral symbolism, and generational continuity. Second, the difference: only in Ngadha is bamboo formally regulated through *ri'i* and *waja*, which combine ecological conservation with cosmological order. This positions Ngadha as a distinctive case of "ritualized conservation"—a practice in which resource management is anchored not only in ecological logic but also in spiritual and customary authority. In doing so, the Ngadha case contributes to global literature by showing how ritual-based institutions can function as models of conservation that remain relevant under modernizing pressures.

Table 4 summarizes Ngadha's position within these cross-regional comparisons. While symbolic parallels exist, Ngadha's uniqueness lies in its more formalized system of ritual-based conservation compared to other communities.

Table 4
Comparative perspectives on bamboo use across regions.

Region/Group	Symbolic/Moral Function	Current Domestic Function	Conservation/Customary Mechanism	Source
Ngadha (Flores, Indonesia)	Collective identity; proverbs on leadership, solidarity, resilience	Declining (displaced by plastic, zinc, concrete)	Formal rituals: *ri'i* (harvest prohibition), *waja* (clump restoration)	Field data; see Sections 3.2–3.3
Apatani (India)	Agrarian symbol, binding agrarian rituals	Declining (replaced by modern materials)	No formal regulation, only cultural practices	[24]
China (Confucian tradition)	Moral symbol: perseverance, humility	Declining (displaced by plastic, steel)	Classification system and varietal TEK	[11, 21–23]
Benin (Africa)	Limited symbol of social status	Still relatively high, but declining	No formal customary mechanism	[29]
Awa (Pacific)	Moral and identity symbol	Almost disappeared from technical use	No customary regulation	[8]
Palawan (Philippines)	Embedded in coastal ecological knowledge and community identity	Maintained in some daily and ritual uses, but under modernization pressure	No formal ritual regulation; integrated with coastal ecological practices	[38]

4.3. Theoretical Implications

Findings from Ngadha show that traditional knowledge of bamboo is not confined to technical rules, but is embodied in skills honed through everyday practice. The dwelling perspective clarifies that practices such as classifying bamboo by age, selecting growth sites, and determining harvest times are not merely procedural steps but outcomes of enskilment—learning embodied through the body, the senses, and social relations [14]. In this sense, Ngadha bamboo knowledge is a form of embodied knowledge enacted in practice, rather than a normative code passed on verbally. Similar dynamics are reported in Sansui, China, where farmers devised bamboo taxonomies grounded in morphological traits and seasonal cycles to guide harvest timing [39]. Similarly, among the Mao-Naga in India, ecological indicators—such as insect behavior, lunar phases, and soil conditions—serve as guides for clump conservation [10]. Both cases highlight *enskilment* as a cross-cultural process within bamboo TEK, albeit expressed in diverse ways.

From a biocultural perspective, the concept of *biocultural resilience* underscores how sustainability arises from the interplay of technical and symbolic dimensions [13]. The Ngadha case (see Section 3.2) demonstrates that clump regeneration is maintained not only through ecological techniques (harvesting in the dark moon phase, selecting culms by age) but also through customary regulations such as *ri'i* and *waja*. The convergence of both strengthens resilience: technical rules safeguard ecological sustainability, while ritual secures social and cosmological legitimacy.

The notion of bamboo as a "material culture of continuity" [26]is also instructive. Ngadha philosophy and *pata dela* frame bamboo as a symbol of leadership, endurance, and solidarity—a transgenerational medium that bridges past and present through practices, symbols, and narratives continually renewed (see Section 3.1).

Theoretically, the Ngadha experience confirms that TEK is not static but adaptive and dynamic: shifting under modernization in the domestic domain, while persisting in symbolic and ritual spheres. This makes TEK a compelling model for culturally rooted strategies of conservation at the global level. Comparative literature in Indonesia—including Dayak *simpukng* [30], Sumedang bamboo groves [31], and Pulau Weh [32], along with debates on supply chains and community capacities [33] reinforce this view. At a global scale, bamboo contributes both to livelihood capitals and ecosystem services [2, 37]. Thus, the Ngadha case can be read as an example of "ritualized conservation" that advances TEK theory: ecological sustainability is not upheld by technical knowledge alone, but institutionalized through symbols, rituals, and collective norms.

4.4. Practical Implications / Policy Relevance

The Ngadha case carries several practical implications for biocultural conservation and sustainable development. First, customary mechanisms such as *ri'i* and *waja* (see Section 3.2) function not only as social regulations but also as instruments of ecological conservation. This contrasts with many contexts in Asia or Africa that rely on technical knowledge without formal customary regulation [24, 29]. In this sense, Ngadha's *ritualized conservation* offers a potential policy model for integrating spiritual and customary dimensions into natural resource governance.

Second, material transformations driven by modernization highlight the need for creative interventions to keep bamboo relevant. In Sumedang, bamboo groves were converted to vegetable plots due to low market value [31]. In Ngada, communities faced managerial capacity constraints when entering industrial supply chains [33]. Policy support is therefore essential—through value-added training (e.g., preservation, lamination, design), creative industries, and equitable market access.

Third, bridging this capacity gap requires participatory and collaborative approaches. Initiatives such as Kanoppi-2 in Eastern Indonesia—implemented in Nusa Tenggara Timur and South Sulawesi with a focus on bamboo-based agroforestry, community forestry, and sustainable value chains [40] —combined with strong local social capital [41],

provide valuable references. Structured knowledge transfer—through training curricula, design clinics, and business incubators—can help connect TEK with the demands of contemporary industry.

Fourth, the systematic inventory of 54 bamboo uses in Ngadha (see Additional file 2) aligns with global calls to expand TEK databases. Participatory documentation, as shown in Yunnan [11], has both methodological and social value: strengthening collective identity, enhancing youth pride, and creating opportunities for collaboration (e.g., with schools and OMK).

Fifth, local programs such as the Hutan Bambu Lestari (HBL) initiative led by Yayasan Bambu Lestari (YBL) can be read as policy experiments that translate *ri'i* principles into technical management. Ethnographic research by the author on *ri'i* bamboo governance (currently under review) further illustrates how interventions such as clump tagging, harvest sequencing, and rotation cycles serve to bridge customary norms with market logics. These practices not only maintain social legitimacy within the community but also provide mechanisms for ensuring supply security, positioning HBL as a hybrid model of cultural conservation and market-oriented resource management.

Sixth, Ngadha's bamboo practices align with both national and global agendas: at the national level, community-based social forestry and creative economy initiatives; at the global level, the United Nations Sustainable Development Goals (SDGs)—specifically SDG 11 (sustainable cities and communities), reflected in the preservation of *sa'o* houses and cultural landscapes, and SDG 15 (life on land), embodied in bamboo clump conservation and biodiversity protection [42].

The integration of technical knowledge with symbolic legitimacy is essential for sustainability. Biocultural conservation is most effective when ecological practices are reinforced by cultural and spiritual values [13]. In Ngadha, the regeneration of bamboo clumps is safeguarded through ecological harvesting practices that are upheld by customary prohibitions, while the symbolic and philosophical significance of bamboo strengthens intergenerational compliance. This demonstrates that culture-based conservation not only ensures ecological continuity but also enhances social cohesion under conditions of modernization.

6. Conclusion & Implications

This study demonstrates that for the Ngadha, bamboo is not merely a material resource but a biocultural pillar that sustains identity, solidarity, and ecological continuity. From the inventory of 54 documented uses to formal rituals such as *ri'i* and *waja*, bamboo has proven adaptive in the face of modernization: while domestic functions have declined, its symbolic, moral, and ritual dimensions remain resilient as a transgenerational medium linking ancestral cosmology with contemporary practice.

These findings carry broader implications. At the global level, Ngadha practices align with the agendas of SDG 11 and SDG 15, showing how *ritualized conservation* can sustain both ecological and cultural continuity. At the local level, participatory documentation emerges as a key strategy to reinforce collective identity, foster pride among younger generations, and safeguard the transmission of bamboo knowledge amidst pressures of modernization.

In sum, Ngadha bamboo TEK affirms that traditional knowledge is not a static inheritance but an adaptive system capable of balancing practical efficiency with symbolic conservation. This experience offers a unique contribution to the global literature on biocultural conservation and opens pathways for policies and sustainable development strategies that place local culture at their foundation. Supporting datasets and extended field materials underlying this study are openly available for verification and reuse (see [43]).

Abbreviations

BPS
Badan Pusat Statistik
HBL
Hutan Bambu Lestari
OMK
Organisasi Muda Katolik
SDGs
United Nations Sustainable Development Goals
TEK
Traditional Ecological Knowledge
YBL
Yayasan Bambu Lestari

Declarations

Ethics approval and consent to participate

This research was conducted (2018–2021) prior to the establishment of BRIN's national ethical approval system. Ethical approval was obtained through the internal review mechanisms of the Research, Development, and Innovation Agency (BLI–KLHK), aligned with international standards including the Declaration of Helsinki. No approval number was issued as BLI–KLHK did not maintain a permit numbering system, but approval was documented in project reports. All participants provided written or verbal informed consent depending on cultural appropriateness. Community elders and ritual authorities granted approval to document traditional knowledge. Consent was recorded in fieldnotes; no standardized forms were used.

Consent for publication

All authors consent to publication. Community leaders provided oral approval for the publication of anonymized data, images, and descriptions.

Competing interests

The authors declare no competing interests.

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Author Contribution

Conceptualization: HMethodology & Fieldwork: HData curation: H, BDP, LRW, LJ, PH, RFormal analysis: H, with input from BDP, LRW, LJ, PH, RWriting – original draft: HWriting – review & editing: H, BDP, LRW, LJ, PH, RAll authors read and approved the final manuscript.

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Data Availability

The dataset(s) supporting the conclusions of this article are available in the Zenodo repository, DOI: 10.5281/zenodo.15258793 (CC BY 4.0) . Additional primary materials (audio, fieldnotes) are available from the corresponding author on reasonable request, subject to ethical review and community confidentiality agreements. Access to culturally sensitive materials follows protocols agreed with Ngadha community representatives.

References

1. Liese W, Welling J, Tang TKH. Utilization of bamboo. In: Liese W, Köhl M, editors. Bamboo: The Plant and its Uses. Cham: Springer; 2015. p. 299–346. https://doi.org/10.1007/978-3-319-14133-6_10.
2. Alamerew AN, Kozak R, Shrestha AK, Zhu Z, Wang G. A Way for Livelihood Improvement: Systematic Review on Bamboo Forest Research. Trees, Forests and People. 2024;16. https://doi.org/10.1016/J.TFP.2024.100571.
3. Chakravarty S, Sen MK, Khiangte L. Evaluating Ferro-Cement and Bamboo as Sustainable Alternatives for Disaster-Resilient Construction. Journal of Structural Design and Construction Practice. 2025;30:04025067. https://doi.org/https://doi.org/10.1061/JSDCCC.SCENG-174.
4. Sharma A, Pawar T, Ji S. Exploring Site-Responsive Characteristics in the Indigenous Architecture of Nyishis of Arunachal Pradesh, India. In: Amaresh Chakrabarti VSPSOMS, editor. Responsible and Resilient Design for Society, Volume 5. Springer Science and Business Media Deutschland GmbH; 2025. p. 65–76. https://doi.org/10.1007/978-981-96-5499-4_6.
5. Borah S, Doloi H. SUSTAINABLE CONSTRUCTION IN THE CONTEXT OF SMART VILLAGES IN ASSAM. ZEMCH International Conference. 2018.
6. Khanum R, Mahadi MS Al, Islam MS. Measuring Efficiency of Bamboo Handicrafts in Tribal Society of Bangladesh: An Empirical Analysis. The Journal of Developing Areas. 2023;57:295–311. https://doi.org/10.1353/JDA.2023.0035.
7. Piper JM. Bamboo and rattan : traditional uses and beliefs. Oxford University Press; 1992.
8. Loving R. Use of bamboo by the Awa. Journal of the Polynesian Society. 1976;85:521–42.
9. Partasasmita R, An'Amillah A, Iskandar J, Mutaqin AZ, Annisa, Ratningsih N. Karangwangi people's local knowledge of bamboo and its role: Implications for management of cultural keystone species. Biodiversitas. 2017;18:275–82. https://doi.org/10.13057/BIODIV/D180136.
10. Lokho K, Narasimhan D. Bamboo - The 'Timber' of Mao-Naga Community. Ethnobotany Research and Applications. 2019;18:1–10. https://doi.org/10.32859/era.18.27.1-10.

11. Cheng Z, Hu X, Fan Y, Fang Q, Lu X, Luo B, et al. Traditional ecological knowledge of bamboo in the Dulong community of northwestern Yunnan, China. Acta Societatis Botanicorum Poloniae. 2023;92. https://doi.org/10.5586/ASBP.9203.
12. Bishnu Maya KC, Lamichhane J, Khanal SN, Gauchan DP. Traditional utilization of bamboo in the Central Siwalik region, Nepal. PLoS One. 2024;19:e0296886. https://doi.org/10.1371/JOURNAL.PONE.0296886.
13. Berkes F. Sacred Ecology. Sacred Ecology. 2012. https://doi.org/10.4324/9780203123843.
14. Ingold T. The perception of the environment : essays on livelihood, dwelling & skill. 2000.
15. Hammersley M, Atkinson P. Ethnography: Principles in Practice: Fourth Edition. Taylor and Francis; 2019. https://doi.org/10.4324/9781315146027/ETHNOGRAPHY-MARTYN-HAMMERSLEY-PAUL-ATKINSON/RIGHTS-AND-PERMISSIONS.
16. Bernard HR. Research methods in anthropology : qualitative and quantitative approaches. 5th ed. Plymouth: Rowman & Littlefield; 2011.
17. Marcus GE. Ethnography in/of the World System: The Emergence of Multi-Sited Ethnography. Annu Rev Anthropol. 1995;24:95–117. https://doi.org/10.1146/ANNUREV.AN.24.100195.000523.
18. International Society of Ethnobiology. International Society of Ethnobiology Code of Ethics (with 2008 additions). 2006. https://www.ethnobiology.net/code-of-ethics/. Accessed 27 Sep 2025.
19. Charmaz K. Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis. London: SAGE Publications; 2006.
20. Emerson RM, Fretz RI, Shaw LL. Writing Ethnographic Fieldnotes. 2nd edition. Chicago: University of Chicago Press; 2011.
21. Wen X, Dong Z. Chinese bamboo metaphors: a cultural cognitive perspective. Lege Artis. 2025;10 1 Special Issue:198–213. https://doi.org/10.34135/lartis.25.10.11.
22. Feng C. The Significance of the Mean in the “Wuji” Section of the Tsinghua Bamboo Slips. Journal of Chinese Humanities. 2024;10:154–74. https://doi.org/10.1163/23521341-12340176.
23. Tao L. The Baoxun Bamboo Manuscript of Tsinghua University and Confucian Daotong Revisited: With a Discussion of Xun Zi’s Status in Daotong. Soc Sci China. 2014;35:190–206. https://doi.org/10.1080/02529203.2013.875656.
24. Rechlin MA, Varuni R. A passion for pine: Forest conservation practices of the apatani people of Arunachal Pradesh. Himalaya. 2006.
25. Hilaly S. Culture of friendship among the apatanis of Arunachal Pradesh. Space and Culture, India. 2018;6:38–50. https://doi.org/10.20896/saci.v6i1.322.
26. Farrelly D. The book of bamboo. San Francisco: Sierra Club Books; 1984.
27. Yeasmin L, Ali MN, Gantait S, Chakraborty S. Bamboo: an overview on its genetic diversity and characterization. Biotech. 2015;5. https://doi.org/10.1007/S13205-014-0201-5.
28. Badan Pusat Statistik Kabupaten Ngada. Ngada Regency in Figs. 2019–2024. Bajawa, Indonesia: BPS Kabupaten Ngada; 2024.
29. Honfo H, Tovissodé FC, Gnanglè C, Mensah S, Salako VK, Assogbadjo AE, et al. Traditional knowledge and use value of bamboo in southeastern benin: Implications for sustainable management. Ethnobotany Research and Applications. 2015;14:139–53. https://doi.org/10.17348/ERA.14.0.139-153.
30. Mulyoutami E, Rismawan R, Joshi L. Local knowledge and management of simpukng (forest gardens) among the Dayak people in East Kalimantan, Indonesia. For Ecol Manage. 2009;257:2054–61. https://doi.org/10.1016/J.FORECO.2009.01.042.

31. Ihsan M, Irawan B, Iskandar BS, Iskandar J. Ethnobotanical study on using bamboo for kites making in Sumedang District, West Java, Indonesia. Biodiversitas. 2023;24:2393–401. https://doi.org/10.13057/BIODIV/D240454.
32. Ritonga MA, Syamsuardi S, Nurainas N, Damayanto IPGP. Ethnobotany of bamboo on Weh Island, Aceh, Indonesia. Ethnobotany Research and Applications. 2023;26:1–19. https://doi.org/10.32859/era.26.75.1-19.
33. Ekawati D, Karlinasari L, Soekmadi R, Machfud. Drivers, Barriers, and Strategies in the Community-Based Supply of Bamboo for Industrial-Scale Bamboo Utilization in Ngada Regency, East Nusa Tenggara, Indonesia. Sustainability 2022, Vol 14, Page 5970. 2022;14:5970. https://doi.org/10.3390/SU14105970.
34. Kafle A, Binfield L, Paudel SK. The commercialization of timber bamboo in Nepal: A SWOT-AHP analysis. Advances in Bamboo Science. 2023;4:100036. https://doi.org/10.1016/J.BAMBOO.2023.100036.
35. Van Hiep T, Tham LT, Thong LM. Analyzing economic performance and value added distribution in the Luong bamboo value chain: A case study of Thanh Hoa province, Vietnam. Trees, Forests and People. 2024;16:100563. https://doi.org/10.1016/J.TFP.2024.100563.
36. Fowler CT. The ecological implications of ancestral religion and reciprocal exchange in a sacred forest in Karendi (Sumba, Indonesia). Worldviews: Environment, Culture, Religion. 2003;7:303–29. https://doi.org/10.1163/156853503322709155.
37. Dutta S, Gorain S, Roy J, Das R, Banerjee S, Gorai SK, et al. Bamboo for global sustainability: A systematic review of its environmental and ecological implications, climate action, and biodiversity contributions. Environmental Reviews. 2025. https://doi.org/10.1139/ER-2025-0032.
38. Hirota I, Tsuji T. Ethno-bamboo Approaches to the Pala'wan in the Mangrove Area of Palawan Island, the Philippines. Southeastern Philippines Journal of Research and Development. 2021;26:47–62. https://doi.org/10.53899/SPJRD.V26I2.153.
39. Luo B, Ahmed S, Long C. Bamboos for weaving and relevant traditional knowledge in Sansui, Southwest China. J Ethnobiol Ethnomed. 2020;16:63. https://doi.org/10.1186/s13002-020-00418-9.
40. World Agroforestry. Kanoppi 2: Developing and promoting market-based agroforestry options and integrated landscape management for smallholder forestry in Indonesia. Bogor, Indonesia: World Agroforestry; 2021.
41. Prasetyo BD, Ekawati D, Handoyo, Djaenudin D, Indartik, Suryandari EY, et al. The social construction of gender relation reality: an analysis of time management applied on sustainable bamboo forestry among families in Ngadha, East Nusa Tenggara, Indonesia. In: IOP Conference Series: Earth and Environmental Science. IOP Publishing; 2021. p. 012016. https://doi.org/10.1088/1755-1315/917/1/012016.
42. United Nations General Assembly. Transforming our world: the 2030 Agenda for Sustainable Development. 2015.
43. Handoyo, Hastuti P, Wibowo L, Prasetyo BD, Surati, Hendarto K, et al. Extended Data for "Ritual Liminality in Crisis: Postcolonial Modernity and the Disenchantment of Ri'i Ecological Governance." https://doi.org/10.5281/ZENODO.15258793.

Figures

Figure 1

Traditional bamboo harvesting in Ngada.

Figure 2

Components of traditional bamboo house (lenga, lat, naja, tubo).

Figure 3

Application of *naja*, tubo, and lat in Ngadha house wall.

Figure 4

Application of lenga in Ngadha bamboo roofs: interior construction (left) and exterior pattern (right).

Figure 5

Tuku hui (bamboo container for storing pork).

Figure 6

Foy doa (*double bamboo flute*) and foy pay (*side-blown flute*).

Figure 7

Bamboo culm segment (leba tibo, two nodes and three internodes) marked with a yellow box.

Figure 8

Contrast between a traditional sa'o house with bamboo/thatched roof (left) and a modern house with corrugated metal roof (right).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1Ngadhaproverbs.docx
- Additionalfile2Bambooutilizationinventory.docx