The Sustainability of Plant Uses on Sumbawa Island since the 13th Century

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Research

Abstract

Background: The contemporary use of plants signifies humanity's adaptive strategies to its environment—a phenomenon that has persisted since the inception of human civilization. This study investigates historical plant use on Sumbawa Island, based on research conducted at the Doro Mpana and Tambora archaeological sites, which date back to the 13th and 19th centuries, respectively. The objective of this study is to elucidate the historical use of plants and their ongoing sustainability, drawing upon archaeobotanical and ethnobotanical data from Sumbawa Island.

Methods: Primary data for this investigation were garnered through excavation, encompassing microbotanical evidence (phytoliths) from the Doro Mpana site and macrobotanical remains from the Tambora site. Secondary data from ethnobotanical publications, were integrated to enhance understanding of the continuity of plant use in Sumbawa Island. The analysis employed a side-by-side comparative method, systematically juxtaposing attributes through tabulation to assess the sustainability of plant use across the two sites.

Results: The use of flora from the *Arecaceae*, *Euphorbiaceae*, *Poaceae*, and *Zingiberaceae* families, as documented at the Doro Mpana site from the 13th century, persists, though it has evolved. The plant species identified at the Tambora site from

the 19th century—including bamboo (*Bambusoideae*), betel leaf (*Piper betle*), candlenut (*Aleurites moluccanus*), rice (*Oryza sativa*), rattan (*Daemonorops* spp.), and sugar palm (*Arenga pinnata*)—continue to be employed in contemporary practices.

Conclusions: The use of plants on Sumbawa Island has been shaped by environmental transformations (e.g., volcanic eruptions) and anthropogenic activities. Traditional knowledge, passed down through generations, remains pivotal in perpetuating plant use. This sustained practice not only reflects the resilience of local communities but also plays a crucial role in biodiversity conservation. By demonstrating the long-term continuity of plant use, this study contributes to a broader understanding of ecological sustainability and the cultural significance of ethnobotanical practices in island ecosystems.

Keywords: Archaeobotany, ethnobotany, plant uses, Sumbawa, sustainability

Background

As a tropical and agrarian nation, Indonesia possesses a remarkable array of plant resources that span from antiquity to the present, underscoring the critical importance of archaeobotanical investigations. In Indonesia, archaeobotanical research—with a particular emphasis on phytoliths—has undergone significant advancements in the last decade (Alifah 2017, Pratama 2020, Amara *et al*. 2023, Zahro 2023). However, most of the existing studies still focus on prehistoric periods (Amara *et al*. 2023). Research that addresses plant use in historical contexts—particularly in relation to environmental events and long-term cultural continuity—remains limited.

Sumbawa is an island in Indonesia situated in the eastern expanse of the Lesser Sunda Islands. This area is endowed with a wealth of biodiversity, which has been harnessed by its inhabitants across generations. Human existence is intricately interwoven with nature, particularly through its plant life. Plants satisfy essential needs for sustenance, apparel, and habitation.

During the zenith of maritime trade from the 15th to the 17th centuries, Sumbawa was chiefly celebrated for its pivotal function as a strategic waypoint along trade routes linking the eastern and western reaches of the Indonesian archipelago, even though it was not a principal exporter of goods (Hagerdal 2017). Nevertheless, other sources indicate that Sumbawa did produce notable commodities such as horses (*Equus caballus*), opium (*Papaver somniferum*), sappan wood (*Biancaea sappan*), and tortoise or turtle shell (*Chelonidae*) (Suryo & Zulkarnaen 2021). Sumbawa has also garnered interest from archaeologists and botanists, particularly concerning the environmental impact of the 1815 eruption of Mount Tambora (Boers 1995, Geria 2010) including its effects on vegetation, climate, and human settlements.

Despite Sumbawa's rich biodiversity, the corpus of information on the taxonomy and ecology of forest formations in West Nusa Tenggara, part of the Lesser Sunda Islands, is notably sparse. This scarcity is attributed to the fact that during the Dutch colonial era, research was primarily concentrated on the collection of flora and fauna from Western Indonesia (Monk *et al*. 1997).

This study serves as an extension of prior investigations on Sumbawa Island at the Doro Mpana and Tambora archaeological sites, adopting an archaeobotanical framework. Insights gleaned from those preceding studies are leveraged to assess the continuity of plant use over time. The sustainability of plant use on Sumbawa Island is particularly intriguing as it synthesizes historical and contemporary data through an archaeobotanical lens across multiple archaeological sites on the island. Current plant use patterns are informed by ethnobotanical research conducted on Sumbawa.

Given the long history of plant use on the island, this study seeks to answer the following research question: How has plant use on Sumbawa Island persisted and adapted from the 13th century to the present, and what factors have influenced its sustainability? By investigating historical and contemporary plant use through an archaeobotanical and ethnobotanical lens, the main objective of this study is to elucidate historical plant use and its persistence through to the present day on Sumbawa Island, naturally evolved and undergone transformations influenced by a variety of factors. This study is expected to provide novel insights into these evolving dynamics.

Materials and Methods

Study area

Sumbawa Island is administratively segmented into four regencies: Bima, Dompu, Sumbawa, and West Sumbawa (Figure 1). The island's demographic landscape is predominantly characterized by two principal ethnic groups: the Mbojo and the Samawa. The Mbojo, also known as the Bima, inhabit the eastern expanse of Sumbawa Island. Conversely, the Samawa predominantly occupy the western and central parts of the island, encompassing the Sumbawa and West Sumbawa Regencies.

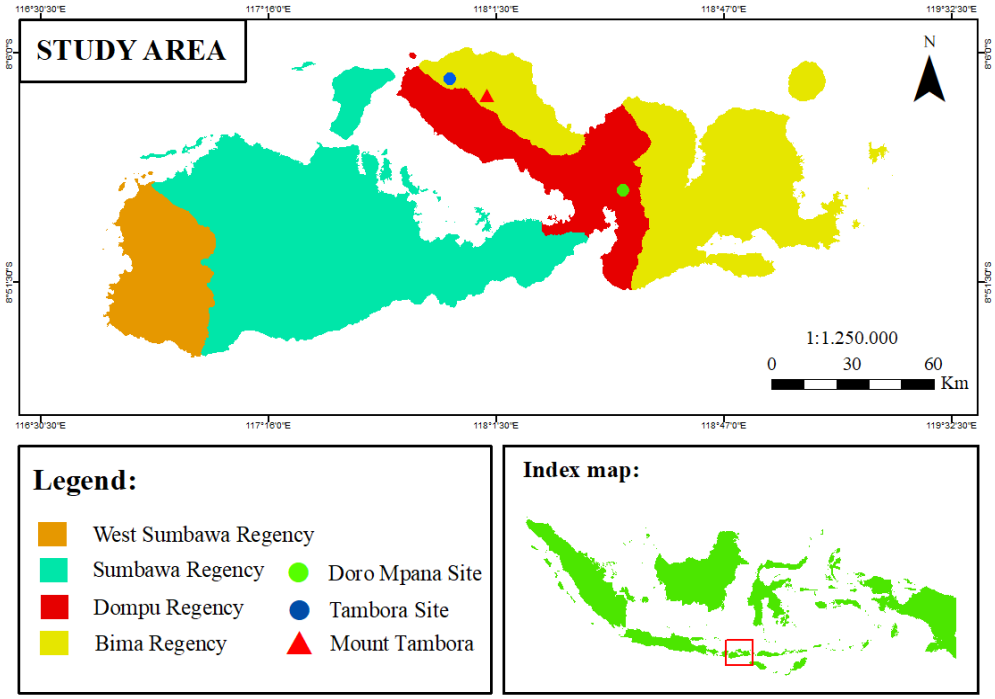

Figure 1. Map of the study area

The rainy season in West Nusa Tenggara typically commences around November and extends through March, resulting in an average duration of approximately five months. Furthermore, by the time the northwestern monsoon winds traverse the western parts of Indonesia before reaching West Nusa Tenggara, the air masses have already expunged a substantial portion of their moisture. As a result, West Nusa Tenggara experiences markedly drier conditions compared to the more western areas of Indonesia (Kirono *et al*. 2016). The area's high clay content influences vegetation growth, leading to a predominance of wetland flora. Notably, the *Dipterocarpaceae* family—which flourishes in the humid southwestern area of West Nusa Tenggara—exemplifies this vegetation (Monk 2000). The *Dipterocarpaceae* plants are renowned for their presence in lowland tropical rainforests and possess considerable economic significance. Land use and changes in vegetation on Sumbawa Island have evolved in conjunction with historical progressions.

In the expedition undertaken by Wiriadinata *et al*. (2013), the southwestern part of Sumbawa Besar Regency, at lower elevations, is predominantly savanna, characterized by grasses interspersed with occasional stands of common arboreal species including *Borassus flabellifer*, *Cassia siamea*, *Lagerstroemia speciosa*, *Schleicera oleosa*, and *Tamarindus indica*. Despite the remaining forest's continued richness in plant diversity, certain areas—particularly those proximate to the settlements of Batu Dulang, Ngengas, Phonik, and Semongkat Atas—have been transformed into coffee plantations. In these plantations, shade trees such as *Erythrina subumbrans* and *Gliricidia maculata* are commonly cultivated. The secondary forest is dominated by species such as *Homalanthus macrophyllus*, *Homalanthus populneus*, and *Laportea stimulans*.

In addition to the transformation of land for coffee cultivation (*Coffea* spp.), Sumbawa—notably in the Dompu and Bima Regencies—has experienced substantial deforestation for maize (*Zea mays*) cultivation. The brisk proliferation of maize plantations has precipitated extensive forest degradation, contributing to heightened occurrences of flooding and landslides (Rachmadi *et al*. 2022).

Data Collection

The objectives of archaeobotanical methodologies include reconstructing ancient environments (Wang 1999), elucidating plant utilization and processing (Alifah 2017, Hidayah 2017, Patridina 2018), ascertaining the functional roles of artifacts (Loy 1994, Fajari 2009), exploring early plant domestication, and tracing patterns of migration or trade (Denham 2011). Archaeobotanical approach was employed on Sumbawa Island, integrating microbotanical data from the Doro Mpana site and macrobotanical data from the Tambora site to elucidate historical plant use on the island. This investigation builds upon our prior research conducted at the Doro Mpana site in 2019. It leverages microbotanical data in the form of phytoliths, which were extracted from excavation contexts and artifact residues. This study analyzed ten sediment samples collected from excavation contexts. In phytolith analysis, there is no universally fixed minimum number of samples required; however, general guidelines are followed to ensure statistical reliability and representativeness. The number of samples collected typically depends on spatial variation and stratigraphic depth. A minimum of 3–5 samples is generally taken per cultural layer or stratigraphic zone. Within each prepared sample, it is common to identify at least 200–300 phytoliths to obtain representative data (Pearsall 2015), though in some cases, 500 or more phytoliths may be counted (Piperno 2006).

One limitation of phytolith analysis lies in the variability of morphotypes, as a single plant species may produce multiple forms of phytoliths (Madella *et al*. 2005). As a result, identification often remains at the family or genus level. Moreover, phytolith production varies among plant species—some, like grasses, produce significantly more phytoliths than others (Piperno 2006). Ideally, phytolith analysis should be complemented by other microbotanical approaches, such as starch grain and pollen analysis, as well as macrobotanical studies, to reconstruct past vegetation more comprehensively (Alifah 2017). In this study, phytolith data were supported by macrobotanical evidence recovered from the excavation, particularly at the Tambora Site.

Phytolith samples were collected from three excavation units at the Doro Mpana site in 2019. The samples were sourced from units S20B1 and S26B6, as well as from unit T1S20, which was also part of the previous investigation conducted in 2018. The sampling process utilized a stratigraphic layer sampling technique, wherein samples were systematically extracted based on observable stratigraphic variations or layers within each excavation unit (Figure 2). Sampling was further informed by variations in stratigraphy and associated artifact discoveries within these units. The technique employed involved poly vinyl chloride (PVC) pipes with an approximate diameter of 6 cm, which were subsequently wrapped in aluminum foil. Each sample weighed around 50 grams. Rigorous care was taken during sampling to avoid cross-contamination between samples (Juliawati *et al*. 2019).

In the case of microbotanical data from the Doro Mpana site, all stages of preparation, extraction, identification, and documentation of soil samples were meticulously executed in the laboratory of the Department of Archaeology, Faculty of Cultural Sciences, Gadjah Mada University (UGM). The extraction and identification procedures adhered to Anggraeni's framework (Anggraeni 2012), with minor adjustments.

The identification stage is carried out by comparing the shape and size of the phytoliths found in the samples with references, literature, books, and online journal sources. One of the references used is the book written by Piperno (2006), titled Phytoliths: A Comprehensive Guide for Archaeologists and Paleoecologists. Another reference used is the International Code of Phytolith Nomenclature (ICPN) (Madella *et al*. 2005), which serves as the basis for classifying phytolith variations based on their morphology.

Plant use data for the Doro Mpana site were additionally derived from phytolith analysis of residues on pottery fragments uncovered during the excavations at the Doro Mpana site in 2018 and 2019. The preliminary findings of this research have been partially disseminated by Pratama *et al*. (2023). The residue analysis of pottery artifacts further revealed the application of pyroprocessing (Pratama *et al*. 2023). Supplementary data were acquired from the Tambora site, emphasizing ecofacts in the form of discernible plant remains (macrobotanical). Examination of these ecofacts was performed on specimens conserved at Gedung Keanekaragaman Hayati BRIN KST Soekarno, Cibinong. Secondary data encompassed scholarly articles related to contemporary plant use practices among the Sumbawan populace, with a focus on scientific literature concerning plant use in Sumbawa and East Sumbawa Regencies (Rochester *et al*. 2016, Rahayu & Rustiami 2017, Jayanti & Sumerta 2022, Rahayu *et al*. 2022). This exhaustive dataset were utilized to elucidate the persistence of plant use practices in Sumbawa.

Figure 2. Locations of sediment sample collection for phytolith analysis at each layer of the excavation unit walls (left: S20B1, right: T1S20)

Data Analysis

The data analysis was conducted by leveraging plant records from the Doro Mpana and Tambora sites as historical references for the flora of Sumbawa Island which span from the 13th–14th centuries and the early 19th century. A comparative assessment was then undertaken with extant plant species, as documented in contemporary ethnobotanical studies, employing the side-by-side comparative method. The purpose of this approach was to distill complex datasets into more digestible formats, facilitating attribute comparison through tabular representation (Esser & Vliegenthart 2017). Following this, the information was synthesized to trace the chronological trajectory of plant usage on Sumbawa Island, shedding light on the continuity of specific species' exploitation.

Subsequent data analysis employed the side-by-side comparative method, systematically juxtaposing attributes from primary and secondary sources. Primary data from phytolith and macrobotanical analyses were categorized based on plant families and species, while secondary ethnobotanical literature provided insights into their contemporary uses. These datasets were then compared through tabulation, identifying patterns of continuity and transformation in plant utilization over time. The results were elaborated narratively, integrating both sources to fulfill the research objective of exploring the sustainability of plant use on Sumbawa Island since the 13th century.

Results and Discussion

Past Environmental Conditions

This study added new data and information about plant use over time to prior archaeological investigations on Sumbawa Island at the Doro Mpana and Tambora sites. A comparable study conducted in 2023 at the Cindai Alus site, specifically the Al-Fatin sector located in Banjar Regency, South Kalimantan, further illustrates this emerging trend. Radiocarbon dates from the site fall between 504–721 AD, and it is interpreted as a settlement once inhabited by the Dayak Ngaju people. Phytolith analysis was carried out and compared with ethnobotanical data on Dayak communities in South Kalimantan and surrounding areas. Based on this analysis, researchers proposed possible plant uses by the site's past inhabitants. Identified plant taxa include bamboo leaves, *Curcuma longa* (turmeric), *Imperata cylindrica* (*alang-alang*), *Nauclea orientalis* (*bangkal*), *Spatholobus littoralis* (*bajakah*), and *Zingiber cassumunar* (*banglai warik*) (Adilia & Mahirta 2023).

The chronological depth of the sites examined in this study focus on historical periods. Radiocarbon dating unveiled that the earliest chronology of the Doro Mpana site traces back to the 13th century (Juliawati *et al*. 2021). Conversely, the chronology of the Tambora site is anchored to the cataclysmic eruption of Mount Tambora in 1815, with the botanical remnants unearthed from archaeological contexts corresponding to that era when the settlement was engulfed by volcanic ash, thus situating these findings in the early 19th century.

Phytolith analysis conducted at the Doro Mpana site reveals insights into the vegetative environment based on phytolith morphology trends. In Indonesia, phytolith analysis remains relatively constrained to identification through classification based on shape. Phytoliths with elongate forms—whether elongate smooth or elongate ornamented, as well as rectangular

or square shapes (Figure 3)—are ubiquitous across various plant species, including trees, shrubs, and grasses. However, some plant species, such as those within the *Poaceae* family, now have more extensive reference shapes (Chen & Smith 2013). Elongate phytoliths, as identified at the Doro Mpana site, are typically associated with leaves from subfamilies such as *Bambusoideae*, *Festucoideae*, and *Panicoideae*. These findings suggest that the Doro Mpana site historically featured an open and relatively arid vegetative environment. Additionally, phytoliths with globular smooth and globular rugose forms were discovered. These globular shapes are commonly produced by plants from the *Arecaceae* family and non-*Arecaceae* families. Plant families known to produce globular forms include *Arecaceae*, *Bromeliaceae*, *Cannaceae*, *Marantaceae*, *Orchidaceae*, *Strelitziaceae*, and *Zingiberaceae*. The phytoliths found at this site were identified as small spheroid/globular smooth and echinate types (less than 3 microns in size) and were categorized as belonging to the *Zingiberaceae* family (Chen & Smith 2013).

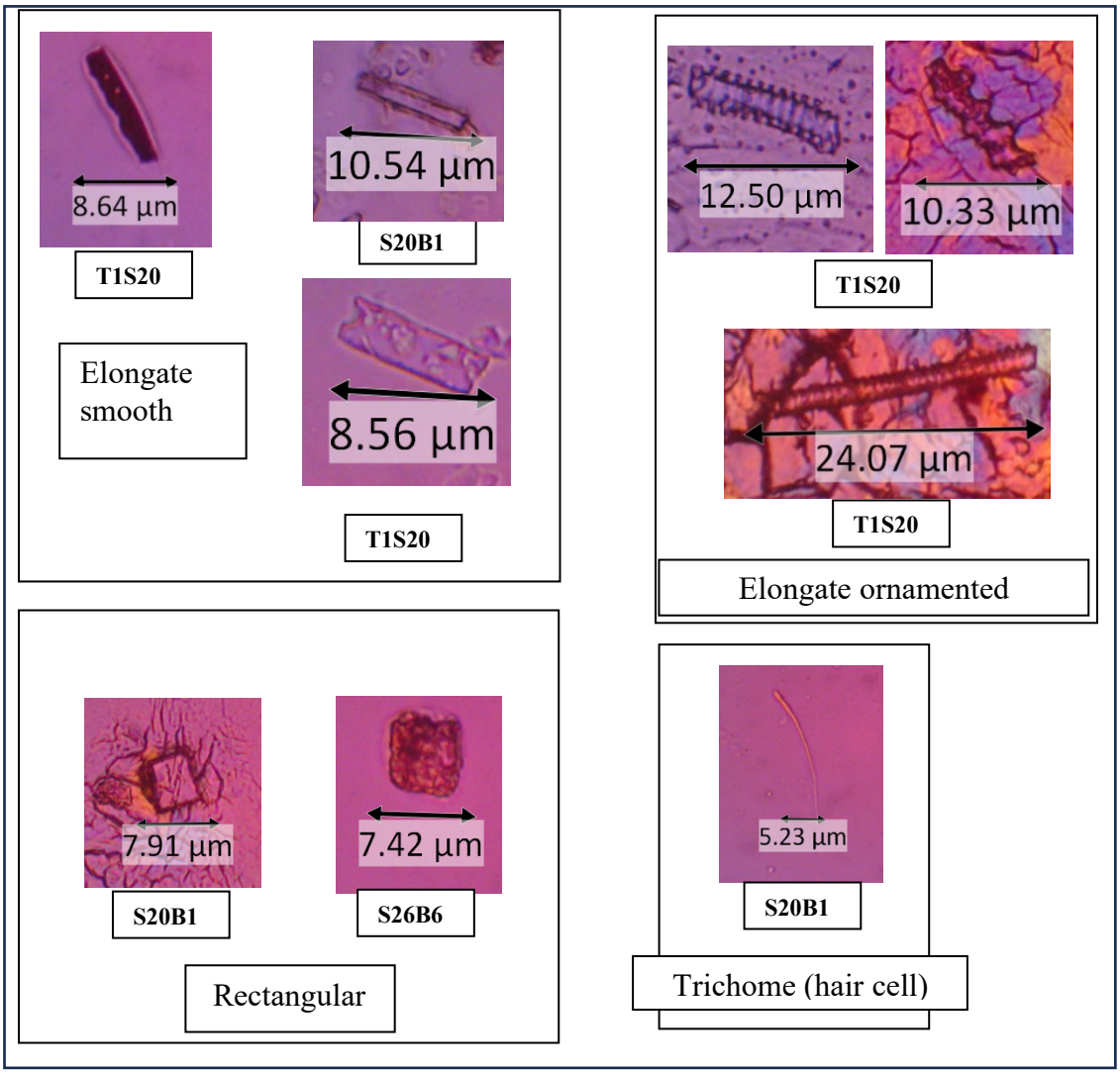

Figure 3. Diverse phytolith morphologies from the Doro Mpana site

Phytoliths of *Poaceae* were identified within the context of skeletal remains and pottery grave goods at the Doro Mpana site. These phytoliths suggest that the vegetation associated with the skeletal remains and grave artifacts represents an open savanna environment, characterized by grasses adapted to arid conditions. Furthermore, an intriguing find was made in box S26B6, which contained no other archaeological artifacts. In layers I and II of box S26B6, at depths of 15 cm and 35 cm respectively, phytoliths with a globular echinate morphology were discovered.

This form, distinguished by its spherical shape and surrounding spines, indicates the presence of palm-like phytoliths (Piperno 1988). The palm family (*Arecaceae*) is known for its distinctive and varied characteristics, exhibiting considerable diversity in both pattern and form. Indonesia is the center of the world's palm diversity, and home to 46 palm genera out of the 215 genera found worldwide (Witono *et al*. 2000). At the Doro Mpana site, the identified palm species include *Arenga pinnata*,

Borassus flabellifer, and *Cocos nucifera*. These plants are presently found in the vicinity of the Doro Mpana site, extending towards the riverine area.

Figure 4. Current vegetation conditions at the Doro Mpana site (left: shrubs and teak trees; right: coconut trees next to the river near the Doro Mpana site)

Specifically, the historical environmental conditions at the Doro Mpana site, as inferred from phytolith analysis, suggest a relatively open and arid landscape. This assessment is limited to the Doro Mpana site, and there are no extant studies investigating the historical environmental conditions across Sumbawa Island. Historically, it is posited that Sumbawa Island was once cloaked in much denser forests compared to the present day. In the 15th century, Javanese settlers commenced their arrival and introduced the practice of cultivating dry rice paddies. Consequently, extensive deforestation occurred. By the 17th century, the proliferation of rice fields escalated, driven by a burgeoning population, particularly immigrants from South Sulawesi who had asserted dominance over Sumbawa. The local populace predominantly sustained themselves through the cultivation of rice (*Oryza sativa*), mung beans (*Phaseolus radiatus*), and maize (*Zea mays*), in addition to trading commodities such as coffee (*Coffea* spp.), cotton (*Gossypium* spp.), pepper (*Piper nigrum*), timber, and horses. Before 1815, principal export commodities included bird's nests, cotton (*Gossypium* spp.), honey and/or beeswax, horses, rice (*Oryza sativa*), salt, and sappan wood (*Biancaea sappan*) (Boers 1995).

A seminal event in Sumbawa's ecological history was the eruption of Mount Tambora in 1815—a cataclysmic occurrence in recorded history (Boers 1995, Geria 2010). This eruption expelled 60–80 megatons of sulfur dioxide into the stratosphere, where it dispersed globally within weeks and underwent oxidation into sulfur aerosols, which subsequently attenuated sunlight. The ensuing climatic perturbations were profound, with 1816 frequently denoted as the "*Year without Summer*" (Brönnimann & Krämer 2016). Switzerland suffered severe agricultural failures, famine, and inundations as a direct consequence of the Tambora eruption (Rössler & Brönnimann 2018). These adversities precipitated widespread malnutrition, which in turn exacerbated immune system deficiencies and potentially aggravated pandemic outbreaks (Fell *et al*. 2020).

Following the eruption of Mount Tambora, Sumbawa plunged into a somber epoch characterized by severe food shortages and burgeoning disease outbreaks. Recovery commenced gradually, as chronicled by J.C. Vetter, who observed that the Kingdom of Bima had resumed agricultural activities after a lapse of five years (Boers 1995). In 1847, naturalist Heinrich Zollinger embarked on an expedition to Tambora. He noted that plant species requiring moist forest environments and deep humus layers might have faced extinction. Extensive tracts of cogongrass or *alang-alang* in Indonesian (*Imperata cylindrica*) began to invade areas that were previously forested. The Tambora eruption catalyzed profound alterations in the agricultural landscape. The cultivated area had significantly contracted in absolute terms, whereas the proportion of pasture or grazing land (formerly rice paddies) had increased (Boers 1995). This shift was further entrenched by the persistent practice of livestock grazing.

Plant Utilization in the Past

The historical use of flora by the communities associated with the Doro Mpana site is discernible through phytolith analysis of pottery residues. This use is delineated into two primary contexts: habitation and burial. In the habitation context, *Poaceae* phytoliths are predominant, exhibiting rondel and bulliform flabellate morphologies. These phytoliths are attributable to the subfamilies *Pooideae* and *Bambusoideae*. Bamboo (*Bambusoideae*) is still extant around the Mboko River, situated approximately 50 meters from the site (Pratama *et al*. 2023). Additionally, phytoliths with a spheroid echinate morphology,

derived from palm-like plants (*Arecaceae*), were identified. Although species such as *aren* (*Arenga pinnata*), coconut (*Cocos nucifera*), and *lontar* (*Borassus flabellifer*) do not occur at the Doro Mpana site, they are found in proximity to the Mboko River (Pratama *et al*. 2023). The presence of palm-like phytoliths in pottery residues suggests that these species were utilized by the Doro Mpana inhabitants. Furthermore, phytoliths with a spheroid ornate morphology were discovered, characterized by irregular forms and minute ornamentations, ranging from 6 to 10 µm, within the *Euphorbiaceae* family. Plants from this family, such as candlenut (*Aleurites moluccanus*) and cassava (*Manihot esculenta*), are prevalent in contemporary Indonesia (Pratama *et al*. 2023).

In the context of burial practices at the Doro Mpana site, the use of plants is documented through phytolith residue analysis of pottery fragments discovered in conjunction with human skeletal remains (Figure 5). These pottery fragments functioned as receptacles for grave offerings (Figure 6). The phytolith residues identified within these fragments are attributable to the *Poaceae* and *Zingiberaceae* families. This suggests that plant use was intertwined with cultural practices influenced by specific belief systems. During the 13th to 14th centuries, the local populace adhered to animistic and dynamistic beliefs—concepts that, while not indigenous, are used in academic discourse to describe these spiritual practices. The Dompu community referred to these traditions as *makakamba* and *makakimbi* (Ismail 2008). The presence of grave goods signifies a cultural tradition of venerating ancestral spirits upheld by the Doro Mpana community (Juliawati *et al*. 2022).

Figure 5. Pottery fragment discoveries on the grave marker stone

Figure 6. Pottery fragments utilized as grave offerings

The use of plants on Sumbawa Island in the following centuries is elucidated through research conducted at the Tambora site, situated in the Dompu and Bima Regencies. The Tambora site—an ancient settlement—was profoundly affected by the cataclysmic eruption of Mount Tambora in 1815. This eruption had far-reaching global consequences, as evidenced by the caldera's remnants, which span an impressive 8 kilometers in diameter.

Excavations at the Tambora site reached a depth of 3 meters, revealing layers of volcanic debris. The plant remains uncovered were macroscopic, permitting direct examination. Among the discoveries was candlenut (*Aleurites moluccanus*) (Geria 2010). Candlenuts were found in substantial quantities and preserved in a charred state. Besides serving everyday purposes, candlenuts were likely a trade commodity, as historical records suggest that the Bima Kingdom exported candlenuts, presumably sourced from Tambora (Salahuddin 1992). Additionally, remnants of betel fruit (*Piper betle*) and rice (*Oryza sativa*) were found, also charred, along with their containers fashioned from woven pandanus leaves (*Pandanus amaryllifolius*) (Figure 7).

Figure 7. Discovery of candlenut (*Aleurites moluccana*), rice (*Oryza sativa*), and betel fruit (*Piper betle*) (intact) in a charred state at the Tambora site (from left to right) (Source: Tambora Research Documentation of Balai Arkeologi Bali, 2009-2010)

Numerous artifacts composed of bamboo (*Bambusoideae*) were uncovered, including a rope likely employed for tethering equines (Figure 8). During the period in question, horses were a prevalent means of terrestrial transport in the mountainous terrain. Additionally, a bamboo (*Bambusoideae*) woven tray was discovered, typically utilized for sifting rice or other grains. Charred remnants of construction materials, including wood and bamboo (*Bambusoideae*), were also identified (Figure 8). Other artifacts included structural components such as a roof framework and various bindings crafted from palm fibers (Indonesian: *ijuk*). Carved wooden panels, presumed to be part of a house's veranda, were also recovered. The analysis of these architectural elements suggests that the Tambora community employed stilted houses aligned with the mountain and oriented northward (Geria 2011). Further findings comprised fragments of a wooden weaving implement and mats constructed from rattan (*Daemonorops* spp.) (Geria 2010). The assemblage from the Tambora site provides insight into how the early 19th-century Tambora community utilized plant resources for clothing, construction, and sustenance.

Figure 8. Discovery of bamboo rope (left) and wooden components integral to the building structure at the Tambora site (right) (Source: Tambora Research Documentation of Balai Arkeologi Bali, 2009-2010)

Sustainability of Plant Utilization in Sumbawa

A significant study on plant use in Sumbawa is the ethnobotanical research conducted on the Samawa community in Batudulang Village, as documented by Rahayu and Rustiami (2017). This investigation meticulously cataloged 41 plant species utilized for dietary purposes, 83 species employed for medicinal and cosmetic applications, 16 species incorporated into construction and artisanal crafts, and 30 species used for apicultural needs, fencing, firewood, nest construction, ritualistic practices, and trade (Rahayu & Rustiami 2017). The study identified a variety of plant families, underscoring the region's rich botanical diversity—a finding that aligns with results from phytolith analysis (Table 1).

Table 1. Comparative analysis of plant species utilized by the Samawa community in Batudulang and phytolith residues identified in pottery fragments from the Doro Mpana site

Use category	Family	Scientific Name	Vernacular Name
Food	*Euphorbiaceae*	*Claoxylon longifolium* (Blume) Endl. ex Hassk.	*Merutis*
	Poaceae	*Dendrocalamus asper* (Schult. & Schult.f.) Backer	*Bambu petung*
	Zingiberaceae	*Amomum gracile* Blume	*Saram*
	Zingiberaceae	*Amomum maximum* Roxb	*Gangsa*
	Zingiberaceae	*Curcuma longa* L.	*Kunyit*
	Zingiberaceae	*Elettaria cardamomum* (L.) Maton	*Kapulaga*
Cosmetics and	*Arecaceae*	*Areca catechu* L.	*Pinang*
Medicine	*Arecaceae*	*Cocos nucifera* L.	*Nyir*
	Euphorbiaceae	*Euphorbia hirta* L.	*Sarat kuku*
	Euphorbiaceae	*Euphorbia thymifolia* L.	*Mata bisa*
	Euphorbiaceae	*Aleurites moluccanus* (L.) Willd.	*Miri*
	Euphorbiaceae	*Bischofia javanica* Blume	*Lintung*
	Euphorbiaceae	*Jatropha curcas* L.	*Jarak*
	Zingiberaceae	*Curcuma longa* L.	*Kunyi*
	Zingiberaceae	*Elettaria cardamomum* (L.) Maton	*Kapulaga*
	Zingiberaceae	*Zingiber cassumunar* Roxb.	*Bangle*
	Zingiberaceae	*Zingiber officinale* Roscoe	*Je*

Building Materials and Crafts	*Arecaceae*	*Borassus flabellifer* L.	*Jontal*
	Arecaceae	*Cocos nucifera* L.	*Nyir*
	Euphorbiaceae	*Aleurites moluccanus* (L.) Willd.	*Miri*
	Poaceae	*Bambusa vulgaris* Schrad. ex J.C. Wendl	*Bambu tutul*
Bee Forage, Bee Nests, Fencing, Firewood, Ritual Materials, and Trade Commodities	*Arecaceae*	*Cocos nucifera* L.	*Nyir*
	Euphorbiaceae	*Aleurites moluccanus* (L.) Willd	*Miri*
	Poaceae	*Bambusa blumeana* Schult.f.	*Bambu duri*
	Zingiberaceae	*Etlingera heyneana* (Valeton) R.M. Sm.	*Goal*

Source: Rahayu & Rustiami (2017), adapted by the authors.

Various plant species utilized for sustenance include forest tubers (*Dioscorea* spp.), locally known as *le'de* or *gadung*. In the Montarang Forest of Sumbawa, the sago palm—referred to as *nao*—is abundant. Historically, the Sumbawan populace depended on wild tubers harvested from the forest for their dietary needs. Today, agricultural fields, as exemplified in Batudulang Village, Sumbawa, are pivotal to the Samawa community's subsistence. These fields are generally situated on elevated terrains, distanced significantly from residential areas (5–10 km). Rice is cultivated in these fields annually, with a cultivation cycle extending over three years. This practice underscores the continual expansion of arable land to accommodate rice production. After three years, the fields are subsequently sown with secondary crops such as cassava (*Manihot esculenta*), maize (*Zea mays*), and sweet potatoes (*Ipomoea batatas*) (Rahayu & Rustiami 2017). The Sumbawa Regency continues to support candlenut trees, which are utilized for daily purposes and have emerged as a vital commodity in Batudulang, alongside coffee (*Coffea* spp.), significantly contributing to the economic fabric of the Samawa community (Rahayu & Rustiami 2017).

Additional prevalent vegetation in Sumbawa includes the lontar palm (*Arenga pinnata*), bamboo (*Bambusoideae*), and rattan (*Daemonorops* spp.). These species thrive in the wild across the forests area. Traditionally, the sugar palm (*Arenga pinnata*) was renowned for its production of alcoholic beverages known locally as *tuak*. Beyond its role in brewing *tuak*, the palm's leaves were extensively utilized in crafting woven artifacts, including bags, wall adornments, hats, and caps. Rattan (*Daemonorops* spp.)—another prominent vegetation—is prolific in Sumbawa's forests and is currently employed in the creation of woven furniture, such as chairs. Apart from that, bamboo (*Bambusoideae*) plays a significant role. Its young shoots, referred to as *rebung* or bamboo shoots, are consumed as a food source. Moreover, bamboo is crucial in preparing a traditional Dompu dish called *timbu*, wherein rice is cooked inside bamboo over a fire. The presence of *Bambusoideae* phytoliths in pottery fragments corroborates the historical utilization of bamboo as a food resource by earlier communities.

Rochester *et al*. (2016) conducted an extensive study identifying 82 EGS (ecosystem goods and services) across nine distinct habitat types in West Nusa Tenggara. The utilization of ecosystem services by local communities predominantly includes bamboo (*Bambusoideae*), candlenut (*Aleurites moluccanus*), coconut (*Cocos nucifera*), rattan (*Daemonorops* spp.), sugarcane (*Saccharum officinarum*), and other plant species (Table 2).

Table 2. The 82 EGS identified from nine habitat types in West Nusa Tenggara

Forest		**Dryland**		**Coastal**	
1	Timber	1	Upland rice	1	Mangrove for timber
2	Honey bee		production (*Padi*	2	Mangrove for crab
3	Palm sugar		*gogo* production)	3	fishery
4	Rattan, Bamboo	2	Soya bean	4	Salt pond
5	Durian	3	Mung bean	Coral reef	
6	Mango	4	Maize	1	Ecotourism
7	Banana	5	Cassava	2	Building material
8	Coffee	6	Peanut	3	Fishery
9	Cacao	7	Vegetables	Inshore	
10	Candle nut	8	Garlic	1	Ecotourism
11	Tamarind	9	Onion	2	Fishing
12	Cashew nut	10	Durian	3	Pearl farm
13	Coconut	11	Mango	4	Seaweed
14	Wildlife hunting	12	Banana	Offshore	

15	Ecotourism	13	Pineapple	1	Brown algae
Wetland		14	Coffee		(*Sargassum*)
1	Rice production	15	Cacao	River,	
2	Soya bean	16	Cashew nut	spring	
3	Mung bean	17	Avocado	water	
4	Maize	18	Coconut	1	Fishing
5	Cassava	19	Jatropha	2	Drinking water
6	Peanut	20	Tamarind	3	Agricultural irrigation
7	Vegetables	21	Tobacco	Ground	
8	Onions	22	Milkfish pond	water	
9	Sweet potato		(*Bandeng* pond)	1	Ecotourism
10	Rambutan	23	Salt pond	2	Drinking water
11	Tobacco	24	Buffalo	3	Agricultural irrigation
12	Milkfish pond (*Bandeng*	25	Cattle		
13	pond)	26	Goat		
14	Prawn pond	27	Chicken		
15	Salt pond	28	Custard apple		
16	Buffalo	29	Sand mining		
17	Cattle	30	Pumice mining		
18	Goat	31	Strawberry		
19	Chicken				
	Red rice				

Source: Rochester *et al*. (2016)

Indonesia is widely acclaimed for its immense biodiversity, particularly in the utilization of flora for therapeutic purposes. It has been documented that 283 plant species are formally sanctioned for use as traditional remedies in Indonesia (Elfahmi *et al*. 2014). The employment of various plant species for medicinal purposes reflects ancestral wisdom passed down through generations. The Sumbawan populace, for instance, has long harnessed plants as medicinal resources. A notable example is the castor plant (*Ricinus communis*), of the *Euphorbiaceae* family, whose leaves are incorporated into herbal concoctions, while its sap is utilized in natural remedies. Another medicinally valuable plant is the jackfruit tree (*Artocarpus heterophyllus*), with its desiccated leaves serving as an ulcer remedy, and the coconut flower (*Cocos nucifera*) applied to treat oral ulcers. Both the Mbojo and Samawa ethnic communities are distinguished for formulating medicinal oils from an array of roots and tree leaves, which are used to heal wounds, alleviate internal disorders, and ease bodily discomforts (Amin *et al*. 1997).

Traditional healing practices remain pervasive among rural populations, heavily reliant on ancestral knowledge transmitted through generations. Moreover, traditional healers serve as pivotal figures in perpetuating these customs. Despite the rapid proliferation of modern medical advancements, traditional medicine retains an essential role within these communities. In certain instances, people resort to traditional remedies after conventional medical treatments fail to deliver the anticipated outcomes, as observed among the Lio people of Flores (Prasetyo *et al*. 2024).

In addition to their applications in sustenance and therapeutics, plants are extensively employed as primary materials in the construction of traditional dwellings. Indigenous houses, such as those belonging to the Mbojo and Samawa tribes, along with the remnants of structures unearthed at the Tambora site, all feature plant-based building components. The traditional abode of the Mbojo people, who inhabit the eastern part of Sumbawa Island, is known as *uma lengge*. Today, *uma lengge* structures can be found in Maria Village, Wawo Subdistrict, Bima Regency. These surviving *uma lengge*—meticulously conserved by the local community—continue to function as storage facilities for provisions. In 1957, there were 117 such buildings, but presently, only 13 remain due to the scarcity and exorbitant cost of cogongrass (*Imperata cylindrica*) (Angelita *et al*. 2019).

The traditional *uma lengge* structure comprises three distinct sections: the foundation, the ground floor, and the upper floor. The foundation is constructed from four stones and supported by four teakwood (*Tectona grandis*) pillars. The ground floor—designated for daily activities—is framed with four teakwood beams. The flooring material consists of bamboo (*Bambusoideae*) and coconut timber (*Cocos nucifera*). The upper floor serves as a repository for provisions and agricultural produce, covered by a roof thatched with cogongrass. Notably, the roof incorporates a *wanga*—an intersecting bamboo

(*Bambusoideae*) framework that symbolizes the enduring fortitude of the Bima people. The attic floor is composed of *kalaba* or areca wood, while the ceiling is crafted from palm (*Arenga pinnata*) (Angelita *et al*. 2019).

The original structure used as a dwelling for the Samawa people was also a stilted wooden house known as *Bale Panggung*, with bamboo (*Bambusoideae*) woven walls and a *santek* roof, made from a segment of *treng* or bamboo (*Bambusoideae*) that is halved, then split again in the middle and arranged like a shingle roof (Figure 9). The stilt house design is an authentic type of Austronesian house (Fox 2006, Telle 2007). This original form of the house is no longer found in Batudulang Village, having been replaced by stilt houses made of stone and cement. However, the *santek* roof is still used for the roofs of rice barns or storage houses. This phenomenon can be interpreted as indicating that *pade* or rice (*Oryza sativa*) holds significant value for the Samawa people. If the *santek* roof continues to be regarded as important, its preservation will likely be sustained (Rahayu & Rustiami 2017).

Figure 9. Traditional *uma lengge* house in Bima

The Dynamics of Botanical Use across Eras

Since the inception of civilization, plants have conferred essential benefits upon humankind, spanning from the earliest acts of plant domestication to contemporary times (Hunt & Rabett 2014). They are indispensable for human existence, providing nourishment, medicinal remedies, energy, and shelter (Radha *et al*. 2021, Anju & Kumar 2024). In parallel, the use of flora by the Sumbawan people can be traced back to the 13th century, as evidenced by research at the Doro Mpana site, employing a series of phytolith analyses in the laboratory. The drawback of this analytical approach is that the botanical data can only be categorized to the family or subfamily level. Specific plant species can be extrapolated through supplementary ethnographic research concerning botanical utilization in the Sumbawa Island. Further corroboration of plant use has surfaced through the discovery of various ecofacts, such as plant remnants, unearthed during archaeological excavations at the Tambora site (Table 3).

Table 3. Evolution of plant utilization from the 13th century to the present day

Family (and Subfamily)	**Usage in the 13th–14th Century (divided into burial and settlement contexts)**	**Usage in the Early 19th Century**	**Contemporary Utilization**
Arecaceae	Settlement	Fiber from the sugar palm (*Arenga pinnata*) was historically used for roofing, and rattan (*Daemonorops* spp.) served as a primary material for household goods such as mats.	The coconut palm (*Cocos nucifera*) is still widely used for construction and food, while sugar palm fiber continues to be employed in crafting household tools, including brooms. Rattan (*Daemonorops*

			spp.) maintains its role in the production of various domestic goods. Furthermore, the sap of the lontar palm (*Borassus flabellifer*) is processed into sugar.
Euphorbiaceae	Settlement	Scorched candlenut (*Aleurites moluccanus*) fragments were found amidst settlement remnants.	Candlenut remains a key ingredient in culinary preparations and as a spice.
Piperaceae	No data	Charred remains of betel plants were found at the Tambora archaeological site.	The practice of chewing betel (*Piper betle*) persists, with betel leaves also playing a role in herbal medicine formulations.
Poaceae			
- *Bambusoideae*	Settlement	Bamboo (*Bambusoideae*) household tools such as ropes and woven baskets were uncovered during excavations. Additionally, bamboo was a principal construction material.	Bamboo shoots (*Dendrocalamus asper*) are consumed as food, and bamboo (*Bambusoideae*) is also integral in traditional culinary practices. Moreover, bamboo (*Bambusa vulgaris*) is widely employed in weaving, construction materials and artisanal crafts.
- *Chloridoideae*	Settlement and burial	No data	No data
- *Festucoideae*	Settlement	No data	No data
- *Oryzoideae*	Settlement	Rice (*Oryza sativa*) remnants were discovered within the Tambora settlement ruins.	Serves as a staple food for the population.
- *Panicoideae*	Burial	No data	Corn (*Zea mays*) is now cultivated as a dietary staple. Cogongrass (*Imperata cylindrica*) continues to be utilized for roofing traditional dwellings.
- *Pooideae*	Settlement	No data	No data
Zingiberaceae	Settlement and burial	No data	*Saram* (*Amomum gracile*), *gangsa* (*Amomum maximum*), turmeric (*Curcuma longa*), cardamom (*Elettaria cardamomum*), *bangle* (*Zingiber montanum*), and ginger (*Zingiber officinale*) are employed as culinary ingredients and in traditional medicine.

Source: Rahayu & Rustiami (2017), Jayanti & Sumerta (2022), Rahayu *et al*. (2022), adapted by the authors.

The use of bamboo (*Bambusoideae*) in the early 19th century closely parallels its contemporary applications as a material for artisanal crafts, planks, and structural elements. It is conjectured that its application as a food resource remains largely unchanged. The identification of rice (*Oryza sativa*) remnants at the Tambora site reinforces its enduring significance as a staple food for the Sumbawan populace. Nonetheless, additional research is required to elucidate the specific rice varieties

uncovered. To this day, rice remains the staple food for the people of Sumbawa and Indonesia in general. A study on the local cuisine of the Sasak ethnic group in Lombok Island, which borders Sumbawa, identified ten plant species with the highest ICS (Index of Cultural Significance) values across all categories and reported uses. These species include *Allium cepa*, *Allium sativum*, *Arenga pinnata*, *Capsicum frutescens*, *Cocos nucifera*, *Elaeis oleifera*, *Oryza sativa*, *Oryza sativa* var. *glutinosa*, *Musa x paradisiaca,* and *Saccharum officinarum* (Sukenti *et al.* 2016).

In conjunction with rice, maize (*Zea mays*) is another prominent crop in Sumbawa. Phytoliths similar to those of maize (*Zea mays*) were discovered at the Doro Mpana site; however, historical records indicate that maize was only introduced to Indonesia in the 16th century by Portuguese explorers. This suggests that the phytoliths may pertain to teosinte (wild corn) (Desjardins & McCarthy 2004), which bears morphological resemblance to maize phytoliths. Presently, maize (*Zea mays*) is a critical economic asset for the inhabitants of Sumbawa Island. Nevertheless, the cultivation of maize on sloped terrain has precipitated deforestation, thereby exacerbating severe flooding in the Bima and Dompu Regencies in recent years (Gustiana & Assifa 2024; Purnama 2025).

Another prominent trade commodity plant in Sumbawa is the candlenut (*Aleurites moluccanus*) (Rahayu & Rustiami 2017). This species—part of the *Euphorbiaceae* family—has been identified through the discovery of phytoliths in soil sediments at the Doro Mpana site, dating back to the 13th and 14th centuries. In addition to candlenut (*Aleurites moluccanus*), other *Euphorbiaceae* members include cassava (*Manihot esculenta*). Like maize (*Zea mays*), cassava (*Manihot esculenta*) was introduced to Indonesia by the Portuguese in the 16th century, suggesting that the phytoliths found may originate from upper or more recent strata (Desjardins & McCarthy 2004). The continued use of candlenut is corroborated by the presence of candlenut (*Aleurites moluccanus*) phytoliths at the Tambora site. Candlenut remains a staple ingredient for the local populace. The persistence of candlenut (*Aleurites moluccanus*) at the Tambora site, along with its ongoing utilization in Sumbawa, substantiates the hypothesis that the *Euphorbiaceae* phytoliths found at the Doro Mpana site are indeed indicative of *Aleurites moluccanus*. Moreover, plants from the *Zingiberaceae* family are widely employed by the Sumbawa community for both culinary and medicinal purposes. In a study on traditional massage oil, plants from the *Zingiberaceae* family are widely used as the main ingredients in massage oil on Sumbawa and Lombok Islands (Rahayu *et al*. 2022). Despite the lack of *Zingiberaceae* phytolith evidence from the Tambora eruption, the relatively short interval of 200 years implies that the utilization of these plants has remained largely consistent with contemporary practices.

An intriguing facet is the application of plants in ritualistic practices, specifically those related to funerary offerings, from the 13th and 14th centuries. Residue analysis of pottery fragments utilized for these burial offerings unveiled phytoliths from the *Poaceae* and *Zingiberaceae* families. The tradition of including offerings in burials was an entrenched custom among the Sumbawan populace before the arrival of Islam in the 16th century. Presently, ritualistic use of plants is no longer prevalent in Sumbawa, primarily due to significant shifts in religious and cultural paradigms, with Islam being the dominant religion on the island. Nonetheless, research by Rahayu and Rustiami (2017) has identified the ongoing use of *Agave sisalana* Perrine from the *Agavaceae* family in rituals designed to repel malevolent spirits—a tradition still practiced by the residents of Batudulang Village, Sumbawa.

As a construction material, bamboo (*Bambusoideae*) has been employed for centuries. Various studies on vernacular architecture in Indonesia underscore the utilization of bamboo (*Bambusoideae*) in the structural framework of residential buildings (Rahmah & Putrie 2021). Bamboo (*Bambusoideae*) is esteemed as a renewable organic resource, distinguished by its unique amalgamation of lightness and pliability, coupled with robust strength and resilience. The plant's ubiquity across the Indonesian archipelago is attributed to its compatibility with the tropical climate, particularly in areas characterized by elevated humidity (Rahmah & Putrie 2021). Over recent decades, the use of bamboo as a construction material has waned, having been largely superseded by concrete and other modern, durable materials. Nonetheless, bamboo (*Bambusoideae*) remains integral to the construction of traditional dwellings in certain indigenous communities, such as those in the traditional villages on the Flores and Sumba Islands (Arisanti *et al*. 2021). In addition to bamboo (*Bambusoideae*), wood fragments in a well-preserved state were discovered at the Tambora site. However, there has yet to be further analysis to determine the specific species of wood present. In contrast to findings by Rahayu and Rustiami (2017), the types of wood historically utilized for construction by the Samawa people include candlenut wood (*Aleurites moluccanus*), coconut wood (*Cocos nucifera*), *keruing* wood (*Dipterocarpus retusus*), *rimas* wood (*Duabanga moluccana*), cottonwood (*Gossypium arboreum*), and *suren* wood (*Toona sureni*).

The continued use of plants from the 13th century to the present—such as bamboo, which is utilized for construction and as food, and candlenut (*Aleurites moluccanus*), used both as a culinary ingredient and for medicinal and cosmetic purposes—

demonstrates the significance of local knowledge in maintaining biodiversity. The people of Sumbawa possess a rich body of indigenous knowledge passed down through generations. However, shifts in land use—particularly on steep terrain—from forested areas to coffee and maize plantations have triggered natural disasters such as floods and landslides. The conversion of forest into dryland agriculture has disrupted soil stability.

Lantung Forest, located in Lantung Subdistrict, Sumbawa, is a prime example of a primary forest that has been transformed into dryland farming areas. As the population around the forest has increased, so has the demand for land. According to data from the Sumbawa Regency Forestry Office, by mid-2020, nearly the entire area of this primary forest—approximately 431.33 hectares—had been converted into dryland agriculture (Febriyan 2022). Flood disasters in various areas of Sumbawa Island have been widely reported in the media. The large-scale cultivation of maize, stretching from coastal areas to hilltops, has led to ecological disturbances that have severely impacted local communities (Gustiana & Assifa 2024; Purnama 2025).

Understanding past patterns of plant utilization can provide valuable insights into sustainable land management strategies rooted in ecological resilience and cultural continuity. Revitalizing traditional agroforestry systems based on indigenous knowledge may serve as an effective measure to prevent further environmental degradation, preserve biodiversity, and support the livelihoods of local communities.

Conclusion

The evolution of plant use over time reflects a continuum of knowledge transmitted across generations. Traditionally, plant applications have spanned essential needs such as sustenance, apparel, and shelter. In Sumbawa Island, however, the role of plants extends to spiritual practices, as indicated by phytolith analyses of pottery fragments found in burial contexts. Over the centuries, the use of plants in Sumbawa has experienced notable shifts, including a decline in their ritualistic use, the displacement of organic materials in construction by more contemporary alternatives, and a growing preference for synthetic pharmaceuticals over traditional herbal remedies.

Sumbawa Island has experienced a series of social and economic metamorphoses, shaped by colonialism, modernization, migration, and natural calamities. Each of these factors has exerted a profound influence on how plants are utilized and managed by the local populace. On the one hand, indigenous knowledge in plant management epitomizes a way of life that harmonizes with sustainability principles. On the other hand, external pressures—such as the proliferation of commercial agriculture and environmental degradation, including land conversion—pose novel challenges to the conservation of the island's natural resources.

To address this challenge, future research is expected to further explore traditional ecological knowledge and the sustainable use of natural resources. Research with multidisciplinary approaches that combine anthropology, ethnobotany, environmental science, and policy studies can provide a more holistic understanding of how traditional ecological knowledge interacts with socio-political structures and ecological changes. Local governments are encouraged to formulate environmentally friendly policies, for instance, by integrating research findings related to environmental conservation into land-use planning and other environmental policy frameworks. Conservation strategies should include systematic documentation of plant species utilized by local communities, particularly those with high cultural significance. Such documentation not only aids in preserving biodiversity but also strengthens the cultural identity and traditional practices associated with ecological stewardship.

Declarations

List of abbreviations: PVC - Poly Vinyl Chloride; ICPN - International Code of Phytolith Nomenclature.
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Consent for publication: Not applicable
Availability of data and materials: Not applicable
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