



Research Article

Agroforestry and Local Wisdom for Sustainable Food Security: A Sembalun Bumbung Case Study

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Abstract | Indigenous communities play a crucial role in preserving cultural heritage, collective identity, and local wisdom passed through generations. However, modernization, climate change, and migration of younger generations pose challenges to the continuity of traditions and agricultural systems. Indigenous agroforestry practices, therefore, have become essential in maintaining food security, ecological sustainability, and social solidarity. This study explores the indigenous agroforestry system and local wisdom of the Sembalun Bumbung community in Lombok in preserving food security and ecological sustainability. Using a qualitative approach with in-depth interviews, participatory observation, and document analysis, this research finds that traditional farming practices, rooted in local customs, have existed since the 8th century CE and continue to evolve with cultural, religious, and modernization influences. The indigenous institutional system (krama adat) plays a key role in safeguarding ancestral knowledge, regulating agricultural customs, and reinforcing social solidarity. Agroforestry practices, focusing on red rice as a primary commodity, are carried out according to customary rules and spiritual rituals like Ngayu-ayu, which not only reflect ecological wisdom but also ensure food distribution via collective granaries. The findings reveal that these customs adapt to modernization and climate change, despite challenges like youth migration and weakened leadership regeneration. Overall, Sembalun's indigenous agroforestry model integrates culture, spirituality, and ecology for sustainable food security.

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Introduction

The global food crisis is one of the most complex challenges of the 21st century. FAO (2022) reports estimate that more than 800 million people worldwide still live-in food insecurity, while

3.1 billion lack access to nutritious meals. This situation has been exacerbated by climate change, urbanization, and population growth, which pressure the availability of fertile land. Meanwhile, intensive monocultural farming models inherited from the Green Revolution, although having once increased

productivity, have proven to cause severe damage in the form of soil degradation, chemical pollution, loss of biodiversity, and increased greenhouse emissions (Li *et al.*, 2021; Wisnujati *et al.*, 2023). As a result, academic and international policy discourses have shifted the paradigm of food security from mere productivity to sustainability, integrating ecological, social, and cultural dimensions.

In such a global context, agroforestry has emerged as an increasingly recognized alternative approach. Agroforestry is understood as a land-use system that integrates trees, crops, and livestock into a mutually supportive ecosystem (Muthee *et al.*, 2022). This system not only enriches food production but also strengthens carbon reserves, reduces soil erosion, and improves hydrological cycles. Studies such as Van Noordwijk *et al.* (2021) in Africa show that agroforestry can play an important role in climate change mitigation and long-term adaptation. Duffy *et al.* (2021) explain that agroforestry can improve the economic stability of farmers through production diversification. However, while global discourse emphasizes the scalability of agroforestry to meet international sustainability goals, there is a critical need to ground these global models in specific socio-cultural and ecological contexts. The success of sustainable food systems often depends on how global ecological principles intersect with localized indigenous knowledge, a nexus that is profoundly exemplified in the high-altitude landscapes of Sembalun. Most international literature tends to emphasize technical-ecological and economic aspects, while social, cultural, and spiritual dimensions remain underexplored.

This is also evident in agroforestry studies in Indonesia. As an agrarian country rich in local traditions, Indonesia has developed numerous traditional agroforestry practices. The Subak system in Bali, leuweung kolot in Baduy, the practices of the Togutil and Tidore communities in North Maluku, as well as shifting cultivation among the Dayak people, illustrate how local wisdom has long integrated ecological, spiritual, and social solidarity principles (Ariani Simabur, 2024; Basuki *et al.*, 2024; Hoagland, 2016; Mergel, 2012; Supyan *et al.*, 2021). These traditional systems prove that agriculture is not just a technical matter of production but also a part of society's cosmology and social order. Some studies assert that indigenous community-based models can support food security as well as maintain ecological

balance (Lam *et al.*, 2019). Yet, most studies on agroforestry in Indonesia still focus mainly on two aspects: its economic potential for farming households and its contribution to environmental conservation. The social-cultural dimension, especially the role of customary institutions, rituals, and community solidarity, has not been adequately considered as a key variable in agroforestry analysis.

Existing literature also demonstrates limitations in linking agroforestry to traditional knowledge systems of indigenous communities. For example, Akram *et al.* (2023) in Lombok highlight the impact of agroforestry on agricultural land conservation, without explaining how these practices relate to value systems or customary structures. However, agrarian anthropology research worldwide, such as that by Vallejo-Ramos *et al.* (2016), shows that indigenous knowledge is a fundamental factor determining the success of an agroforestry system. If this dimension is overlooked, any analysis of agroforestry-based food security will always remain incomplete, missing the epistemological and cosmological foundations underpinning indigenous actions. By situating the Sembalun Bumbung case within this framework, this study bridges the gap between the broad global imperatives for climate-resilient agriculture and the highly localized spiritual-ecological management systems that sustain indigenous livelihoods. Another gap in existing literature is the lack of interdisciplinary research connecting agroforestry to social change. Many studies end at the descriptive level such as describing intercropping techniques, planting patterns, or dominant crops but rarely link them to the dynamics of modernization, migration, and tourism increasingly affecting indigenous communities. Research in Southeast Asia shows that modernization often leads to significant transformation in traditional agricultural practices (Rambo, 2017), but studies with particular focus on Lombok, especially the Sembalun community, remain rare.

These conditions indicate wide research opportunities to position agroforestry not merely as an ecological practice, but as a knowledge and social system integrating ecology, spirituality, and culture. This makes research on the Sembalun Bumbung indigenous community relevant. This community has a long history since the 8th century CE, influenced by Buddhist, Hindu-Majapahit, and Islamic traditions, yet preserves red rice as a cultural and spiritual

symbol. The customary system regulates planting and harvesting through *tokoh penuntu*, the Ngayu-ayu ritual as a form of gratitude to nature, and *bale lumbung* as a collective food reserve, demonstrating that agroforestry in Sembalun cannot be understood without linking it to local wisdom. Today, however, these practices face severe pressures. The influx of horticultural crops like garlic and carrots, harvested in short cycles, has led many farmers to switch from red rice. The booming tourism sector in Sembalun attracts the youth to work in the service industry, leaving traditional farming behind. Modernization through the use of chemical fertilizers and pesticides has shifted environmentally friendly practices passed down from ancestors. Furthermore, the regeneration of indigenous leaders has weakened, leaving some customs neglected. This phenomenon illustrates a major dilemma: how to sustain local wisdom amid powerful waves of modernization. Literature indicates that agroforestry studies in Lombok are still dominated by technical and economic analyses. Studies on the social and cultural dimensions supporting agroforestry practices especially regarding customary institutional structures, spiritual rituals, and social solidarity are still very limited. Thus, a comprehensive understanding of Sembalun Bumbung indigenous agroforestry has never truly been unveiled in depth.

This is the distinguishing feature of this study. It does not merely document planting techniques or crop diversification patterns but posits indigenous agroforestry as a holistic knowledge system. Ecological, cultural, spiritual, and social solidarity dimensions are understood as a unified framework shaping the community's food security paradigm. Such an approach is rarely taken in previous studies, locally or internationally. The main contribution of this research is its boldness to connect agroforestry practices with non-material dimensions often omitted from food security analysis. In many studies, food security is measured by availability, access, and consumption indicators, but rarely connected to rituals, cosmology, and value systems. Through the Sembalun Bumbung case, this study shows that food security is not just about production, but also about customary legitimacy, collective solidarity, and honoring nature as a spiritual entity.

This study also offers a new reading on the dilemma of modernization. While many studies see modernization as a threat to traditional practices, this

research demonstrates that indigenous communities have creative adaptation strategies. The legalization of customary institutions through notarization and recognition from the Ministry of Law and Human Rights (Kemenkumham), for instance, shows how ancestral traditions are adapted to modern legal requirements without losing their spiritual essence. These findings enrich academic discourse by affirming that traditions are not static, but dynamic, adaptive, and constantly seeking intersection with changing times. Thus, this research not only fills gaps in literature but also broadens perspectives on food security. Sembalun Bumbung indigenous agroforestry is positioned as an alternative model emphasizing the close connection between humanity, nature, and spirituality. This model is not only relevant locally but possesses universal value as inspiration for sustainable development amid food and climate crises. Based on this framework, the purpose of this study is to analyze the Sembalun Bumbung indigenous agroforestry system in Lombok in its integration with local wisdom, cultural values, spirituality, and social solidarity for the preservation of food security and ecological sustainability.

Materials and Methods

Research type, approach, and location

This research uses a qualitative approach with an ethnographic design. This design is chosen because the study focuses on understanding the meanings, values, and indigenous agroforestry practices of the Sembalun Bumbung community, which are rich in symbols, rituals, and local wisdom. Ethnography is deemed relevant to examine the everyday life patterns of indigenous peoples, including how they perceive relationships with nature and spirituality through their farming system (Turner *et al.*, 2022; Zidny *et al.*, 2020). The research was conducted in Sembalun Bumbung Customary Village, Sembalun District, East Lombok Regency, West Nusa Tenggara. The location was selected purposively, as the community still practices agroforestry based on red rice, maintains indigenous rituals such as Ngayu-ayu, and possesses indigenous institutional systems (Krama Adat) and *bale lumbung* as symbols of food sovereignty. This location selection follows the purposive site selection principle commonly used in ethnographic research (Baltes and Ralph, 2022).

Subjects and key informants

The research subjects are the Sembalun Bumbung

indigenous community, while key informants are chosen through purposive sampling based on their authority, expertise, and deep knowledge of indigenous customs and agriculture. The selection criteria focused on individuals who hold structural positions within the krama adat (customary institution), possess hereditary knowledge of traditional farming rituals, or have actively practiced indigenous agroforestry for more than 20 years. These criteria ensure that the data obtained reflect both the formal customary regulations and the practical implementation of local wisdom. The main informants consist of:

- Head of customs (1 person) as the highest authority in indigenous decision-making.
- Indigenous priests (4 people) responsible for spiritual matters, rituals, and religious symbols, such as guardians of the Zam-Zam Well, Batara Guru, Majapahit, and Seketi Dewi Asih.
- Penuntu (1 person), a customary leader initiating the red rice planting season.
- Senior indigenous farmers (2 people) practicing daily agroforestry.
- Community and indigenous women leaders (2 people), responsible for post-harvest management, social rituals, and collective activities.

The total number of purposively selected primary informants is 10 individuals. This number was then expanded through snowball sampling to include 8 additional figures, including local youth representatives and agricultural extension officers, to reach data saturation and provide a multi-perspective view on modernization pressures. Thus, a total of 18 informants participated in this study. The use of purposive and snowball sampling is standard in ethnographic research as it enables researchers to access authoritative and representative informants (Kataeva and DeYoung, 2017).

Data analysis technique

Data were analyzed interactively following the Miles and Huberman (2009) model, encompassing three stages: data reduction, data presentation, and conclusion drawing. Data reduction was performed by selecting and summarizing relevant information obtained from interviews, observations, and documentation. Data presentation organized materials into themes such as community history, indigenous institutional structure, agroforestry practices, spiritual rituals, gender roles, and food security. Conclusions were drawn by identifying patterns among themes and verifying them through

triangulation and reconfirmation with informants (member check).

Validity testing

Data validity was reinforced through source, method, and time triangulation (Denzin, 2008). Source triangulation was carried out by cross-checking data from the head of customs, indigenous priests, penuntu, and senior indigenous farmers. Method triangulation matched interview results with observations and documentation. Time triangulation involved data collection at different moments, such as during planting season, harvest, and customary rituals. Additionally, member checking was employed to confirm findings with key informants, ensuring the researcher's interpretations aligned with community understanding.

Results and Discussion

History and origins of the sembalun bumbung indigenous community

The issues surrounding cultural heritage management are a fundamental concern in focusing on cultural preservation itself. Hidayat et al. (2025), in his research, explains that indigenous communities act as the front line in safeguarding traditional practices and values, ensuring that cultural practices remain renowned and timeless. Through the process of interaction, the community then strengthens their identity according to their unique cultural patterns (Rosenmann et al., 2016). Kerama adat, or customary labor, can be interpreted as one of the manifestations of establishing a community on the slopes of Mount Rinjani, namely Sembalun Bumbung, which has a long history originating from the earliest periods of civilization in this region.

Based on interviews and observations of subjects and informants during the study period, it was found that the existence of this indigenous community predates the emergence of major kingdoms such as Singasari and Majapahit, and even the establishment of formal governmental institutions. According to the statement of the Ketua Adat (customary leader) of Sembalun Bumbung, which took place at the cultural heritage site of Bale Adat Sembalun on Tuesday, July 8, 2025, the following is an excerpt from the interview with Informant 1:

This Desa Beleq was established around the year 800.

Ultimately, the first humans in Sembalun were a pair of husband and wife named Lebe Beleq and Lakiq Beleq. They are the ones we first commemorate during traditional celebrations. After five generations from them, the village was built in the year 800, during the golden era of Lombok Island's history. According to interviews with traditional leaders, the earliest humans to reside in this area are believed to be Lebe Beleq and Lakiq Beleq. From this couple descended the earliest generations of the Sembalun community. After five generations, the initial settlement known as Desa Beleq was formed, around the 8th century AD. This village already possessed a well-structured social and spiritual order, even though its people at that time still lived simply and were not fully acquainted with complex social customs.

Entering the 9th to 10th centuries, Buddhist teachings began to enter the Sembalun region, brought by a figure known as Buddha Cortana. This figure is also believed to have introduced red rice seeds and Sulaiman wood, as well as new ways of living and dressing. Physical evidence from the Buddhist era such as the Sabur scripture, firearms, and ancient tombs are still preserved in traditional houses to this day. Around the year 1257, a major volcanic eruption occurred, which is believed to have shaped the current geological conditions of the region. In the next phase, around the 14th century, the influence of the Majapahit Kingdom arrived and changed the community's belief system to one that was Hindu-Javanese in character. This is evidenced by the existence of Majapahit tombs and changes in the customary leadership structure, which began to adopt a royal system. Then, between the 15th and early 16th centuries, Islamic teachings entered the region through Sunan Ampel, who brought a Quran bound in camel leather and wooden manuscripts directly into Bawa Dewa (Desa Beleq). This brought about major change the name of the village was changed to Sembahulun, meaning "to surrender to God, which became the origin of the name Sembalun as we know it today (Nna, 2015).

The interview conducted with Informant 2 took place on Wednesday, July 9, 2025, at the residence of Informant 2. The following is the result of the interview with Informant 2 regarding the history of Sembalun: Sembahulun became Sembalun Lawang and Sembalun Bumbung. "Lawang" means "gate"... while here, "kekelong" means "granary" or a place to store harvests.

Based on Informant 2's statement, the Sembalun region developed and eventually split into two entities: Sembalun Lawang, which means entrance gate, and Sembalun Bumbung, which means granary, a place for storing agricultural yields. The division of territory naturally accompanies the cultural influences arising from a series of historical events. The community that established this civilization also created its own unique cultural patterns, resulting in a system of social control that became the foundational order for local society as a krama adat community. Within this context, krama adat is incorporated into community regulations, encompassing rules for planting red rice, the Ngayu-ayu ceremony as an expression of gratitude to nature, and customary structures that include various pemangku and penuntu spiritual leaders.

Social structure and customary institutions

Within the social structure of the Sembalun community, the institution located at the cultural heritage site of Bale Adat Sembalun is known as krama adat. The krama adat serves multiple functions: it safeguards ancestral heirlooms, oversees the implementation of customary procedures handed down across generations, and positions respected figures as protectors of ancestral heritage. In Sembalun Bumbung's historical tradition, ancestral objects and the careful transmission of customary practices are regarded as sacred and are carried out with great attention. Therefore, the structure of the Sembalun customary institution is led by the Ketua Adat (customary chief) and his administrative team, who are also referred to as prabekel or pakubumi. The institution includes various pemangku adat (customary functionaries) with specific areas of responsibility, such as the penuntu (the leader of planting activities), and a group of Kiyai tasked with religious affairs. Based on an interview with Informant 3 regarding the structure of the customary institution in Sembalun, conducted on Wednesday, July 9, 2025, the following is explained:

The customary leadership structure still exists. It begins with the Ketua (chief), and includes the Pemangku of Sumur Zam-Zam, Batara Guru, the Majapahit Pemangku, and the Pemangku of Seketi Dewi Asih. In fact, all of these office bearers are actively involved in customary agricultural activities and major ceremonies such as Ngayu-ayu. One important figure within the customary structure is the Penuntu, who serves as the leader who inaugurates

the planting and harvesting season for red rice. Community members are not permitted to plant or even take harvested crops from the bale lumbung before the Penuntu gives his signal.



Figure 1: Interview with the traditional leader of Sembalun Bumbung.

Based on the above interview, the krama adat institutional system possesses both customary and governmental structures, whose primary function is to preserve the values and norms upheld by the local community. The inheritance of positions within the customary structure is based on lineage. However, if no suitable successor is available, the customary post may temporarily be filled by the closest relatives. This demonstrates a degree of flexibility in ensuring the continuity of traditions. In addition to its administrative framework, the social system in Sembalun Bumbung highly emphasizes the values of mutual cooperation (gotong-royong) and solidarity.

Indigenous agroforestry system and traditional farming patterns

The indigenous agroforestry system in Sembalun Bumbung is a hereditary practice rooted in customary regulations and ancestral spirituality. Red rice serves as the primary crop and is regarded as a symbol of heritage and blessing. The planting process cannot be carried out freely, as the community is only permitted to begin cultivation after the customary leader known as the penuntu carries out the initial planting. This was affirmed during an interview with Subject 2 at their residence on Thursday, July 10, 2025. Subject 2 stated that: For rice, the one who plants first is called the penuntu. It must be started by him. The community is not allowed to plant before the penuntu does so. This is a customary rule.

Based on the interview with Subject 2, it is known that the indigenous agroforestry system in Sembalun Bumbung is an integrated form of agriculture that relies not only on ecological aspects, but is also

deeply rooted in customary values, spirituality, and local wisdom passed down through generations. One of the main aspects of this system is the respect for customary rules in the cultivation process, especially in the planting of red rice. The agricultural pattern is regulated by a customary timeline called mapakin, which is determined by customary functionaries such as the Pemangku of Sumur Zamzam, Batara Guru, and the Pemangku of Majapahit. Planting may not commence without this ritual, and the harvest may not immediately be taken home.



Figure 2: Sembalun red rice.

In this case, it can be concluded that agroforestry under customary law holds a very central role the prohibition against planting before the penuntu does so reflects the existence of binding customary rules that are collectively adhered to, forming a legal culture consistently upheld by the community (Chua *et al.*, 2019). Agroforestry practices in Sembalun not only maintain ecosystem sustainability through intercropping or conservative planting patterns, but also serve as the implementation of customary values that are alive within society (Leksono and Zairina, 2022). The awig-awig regulates various agricultural aspects, such as the timing of planting, permitted crop types, distribution of yields, and land use based on both spiritual and ecological values (Gill *et al.*, 2019).

Local wisdom and traditional rituals in agriculture

Local wisdom in agriculture in Sembalun Bumbung

is reflected in agroforestry practices that prioritize harmonious relationships between humans and nature. The local community preserves ancestral traditions through rituals involving spirituality and natural resource management. One important ritual is Ngayu-ayu, which means “befriending the universe” and is intended to ensure the sustainability of agricultural yields. In an interview conducted on Tuesday, July 8, 2025, the Ketua Adat as Informant 1 explained that: We must be grateful to the Almighty and spiritualize it by slaughtering a buffalo, as the earth’s stakes (pasak-pasak bumi).

Based on the interview with Informant 1, this ritual involves the slaughtering of a buffalo and the burial of its head as a symbol of gratitude to the ancestors who shaped the land. The Ngayu-ayu ritual also serves as a means to maintain harmonious relationships among people and with the universe, so that the impact of these actions will foster environmental sustainability as aspired (Yasir *et al.*, 2023). Meanwhile, Dewi Anjani is positioned as the guardian spirit of Mount Rinjani. The ritual of Ngayu-ngayu functions as a medium and means to express gratitude to Allah and to honor Allah’s guardian (Astina *et al.*, 2021).



Figure 3: *Ngayu-ayu ritual of planting buffalo head.*

In the Ngayu-ayu traditional ritual, the traditional Lombok rice granary is not merely a structure for storing harvests, but also a symbol of prosperity, food security, and local wisdom of agrarian society (Rivera-ferre *et al.*, 2021). Constructed from natural materials such as bamboo and alang-alang grass, this structure reflects the community’s ability to utilize local resources sustainably and in harmony with nature (Josiah Marut *et al.*, 2020). However, with advancing tourism and globalization, its function has shifted the granary is now often used as an aesthetic element in the promotion of cultural tourism, and has

lost its primary role within the agricultural system (Montalvo-Romero *et al.*, 2023).

Through interviews and observations with subjects and informants throughout the research period regarding the series of local wisdom in the Sembalun community, an interview was conducted with Subject 2 at their residence on Thursday, July 10, 2025. Subject 2 revealed: Now, this is not yet finished. Even until returning the rice from the field to the home granary, there are rules. Before the penuntu returns his rice, the community is not allowed to take theirs home. It must wait one month in the field.

Based on this interview with Subject 2, this rule shows that although the granary has experienced a physical shift in function, its associated values and rituals remain strongly preserved in the community’s spiritual and social life. The tradition of waiting one month before rice is moved from the field to the granary reflects respect for the agroforestry-based natural cycles.



Figure 4: *Bale lumbung.*

Gender roles and division of labor in agroforestry

The indigenous agroforestry system in Sembalun Bumbung demonstrates a naturally occurring gender-based division of labor, where the roles of men and women are shaped culturally and spiritually within the context of daily life. Men hold a crucial role in the initial stages of agricultural production and in matters of symbolic significance, such as customary rituals, land preparation, initial planting, and the transport of harvests to distribution points. This role also includes important structural positions within the customary system, in which men are appointed as pemangku adat, penuntun (planting season leader), and penghulu, who regulate the timing of planting and harvesting according to custom.

In an interview conducted on Tuesday, July 8, 2025, the Ketua Adat (traditional leader) as Informant 1 explained:

The role of men is more dominant in rituals (as

pemangku and penghulu), whereas the role of women may be stronger in household management and post-harvest processes.

Based on the interview with Informant 1, the division of labor between men and women in the indigenous agroforestry system of Sembalun Bumbung occurs organically and is influenced by cultural and spiritual factors. [Hornby and Hull \(2023\)](#) research also indicates that men have a more dominant role in the early stages of agricultural production and in customary rituals. Men are involved in land management, planting, transporting agricultural produce, and hold key positions in the customary structure as Pemangku Adat, Penuntun, and Penghulu. These roles reflect their responsibilities in managing the planting and harvesting schedules ([Kaschuk et al., 2022](#)).



Figure 5: Dominance of male roles in the Ngayu-ayu tradition.

Women play a significant role in post-harvest management as well as in supporting the sustainability of social and cultural activities. They are actively involved in drying, storing, and processing harvests, as well as in providing food for customary events. In the context of customary mutual cooperation (gotong-royong), women bring rice, sugar, and cooking oil, while men bring coconuts and wood as part of their collaboration in both customary ceremonies and family celebrations.

The involvement of women is not limited to the domestic sphere. In agricultural activities, women's labor is also highly relied upon for planting, weeding, and harvesting demonstrating that the sustainability of agriculture is highly dependent on the collective contributions of both genders ([Doss et al., 2018](#)). Agricultural work is carried out by all family members, including housewives, with the aim of increasing household income and maintaining

family food security. This aligns with the findings of [Ramirez-Santos et al. \(2023\)](#), who states that in traditional agriculture systems based on custom, the roles of women are not just supportive but are active actors in sustaining ecological and social systems. The work division while different is not unequal between men and women; rather, it reinforces the value of collectivity and harmony in the Sembalun community ([Orazani et al., 2023](#)).



Figure 6: The role of women in the Ngayu-ayu Tradition.

Agroforestry-based food security

Agroforestry-based food security refers to an integrated system that combines agriculture, forestry, and local wisdom to ensure the continual availability, access, and stability of food in a sustainable manner. This statement is also supported by the results of the interview with Informant 1 on Wednesday, July 9, 2025, who stated:



Figure 7: Agricultural commodities of the sembalun bumbung community.

Here, the main staple from the beginning is red rice, but according to customary rules, the process is lengthy, and involves several stages, starting from seeding, planting, and finally, the rice is only taken out of storage following the penuntu. The most important crop is rice, but there is also native coffee growing along field edges the small-leaved Sembalun coffee. In addition to this, there is arabica coffee, as well as strawberries, beans, cabbage, carrots, garlic, shallots, and lettuce. For rice, the one who plants first is called the penuntu. He must start first. The community is

not allowed to plant before the penuntu does so. This is a customary rule. Once the penuntu has planted, the rest of the community may begin, but the location is flexible, not restricted to one place.

Based on the above interview, it is evident that food security in Sembalun is not only built on agricultural yields but also through a combination of food systems, local customs, and cultural values. Agroforestry enhances the sustainability of natural resources and the environment by maintaining soil fertility, supporting hydrological functions, conserving carbon reserves, reducing greenhouse gas emissions, and supporting biodiversity (Abbas *et al.*, 2017). This illustrates an agroforestry system that relies on biodiversity, so the community is not dependent on a single food source. Such diversification creates production stability throughout the year and increases overall food security (Norgrove and Beck, 2016). Furthermore, planting processes which must adhere to customary rules and begin with the penuntu reflect the role of local wisdom in scheduling, maintaining social and ecological harmony, and ensuring agricultural practices are carried out with spiritual and collective awareness. This strengthens the sustainability aspect of the agroforestry system.

Such an agroforestry system is implemented through customary practices, such as red rice planting, that follow both spiritual and social stages. This is validated by the interview with Informant 2 on Wednesday, July 9, 2025:

If we talk about Ngayu-ayu, it means befriending the universe, and we must remain continuous, be friendly, and maintain continuity.

From the interview above, it is found that the Ngayu-ayu ritual within the Sembalun agroforestry system contains several essential elements: respect toward nature as a partner in life, scheduling crop cycles that allow the earth time to recover, and a moral obligation to return what has been taken through restoration efforts. This tradition is not only a reflection of harmonious relations between humans and nature, but also serves as a mechanism for managing resources that preserves soil fertility, water availability, and crop sustainability.

In addition, the bale lumbung has a central role in supporting the food security of the Sembalun

community. According to the interview with Informant 3 on Thursday, July 10, 2025:

Bale lumbung is where red rice is kept, so that even during famine we still have reserves. In the past, every house had a granary, but now, more is stored collectively so management and distribution are easier when needed.

Bale lumbung functions not only as a storage facility for red rice but also as a symbol of social solidarity and food sovereignty. With the existence of collective granaries, the community is able to ensure the long-term availability of food, anticipate seasons, and distribute yields fairly to community members in need. This role strengthens agroforestry sustainability, because harvests are not consumed or sold immediately, but are stored as strategic reserves. This agroforestry system has demonstrated its ability to adapt to climate change and environmental challenges through local knowledge and land management based on customary values. This is also reflected in the interview with Subject 3 on Wednesday, July 9, 2025:

Besides rice, because the harvest period is long and there is climate change things used to be very cold and muddy, but now it's different; there is a lot more coffee, brought by the Dutch, and many new plants, so people have harvests every day.

Based on the above interview, it can be concluded that the agroforestry system in Sembalun has adapted well to climate and ecological challenges by relying on local knowledge, long-term observation, and customary principles. The system displays strong environmental adaptation, and a stable diversity index reflects ecosystem balance (Marsden *et al.*, 2020). Despite facing challenges such as modernization, dependence on chemicals, and weakened regeneration of customary leaders, the Sembalun community continues to maintain its food security through social collaboration, respect for nature, and the transmission of ancestral values across generations. Indigenous agroforestry in Sembalun stands as concrete evidence that food security is not solely about production, but also about culture, spirituality, and social solidarity.

Ecological sustainability and adaptation to climate change

The indigenous agroforestry system in Sembalun demonstrates how ecological sustainability and adaptation to climate change can be achieved through

local knowledge and cultural values. The threats and vulnerabilities caused by climate change encourage the community to undertake adaptive measures (Bardosh *et al.*, 2017). The integration of economic, social, and cultural values allows vegetation changes to progress in tandem with gradual social and cultural transformations, thereby enabling adaptation to climate shifts (Swanson, 2015). This is reinforced by the results of the interview with Subject 4 on Thursday, July 17, 2025, who stated:

This shows the community's growing awareness of climate change as it happens gradually. They adapt their crops, planting patterns, and even building methods in accordance with new conditions.

Based on the above interview, it is concluded that adaptation to climate change is not undertaken instantaneously, but rather through gradual changes in agricultural practices and daily life that are continually adjusted to the changing natural environment. People in Sembalun have altered their building materials and settlement patterns, even though such changes also influence thermal comfort, indicating the ecological consequences of structural adaptation. Adaptation is understood as action taken to minimize vulnerability and increase resilience, whereas adaptive capacity refers to the community's ability to take such action. The adaptation agenda is always integrated with livelihood strategies as it relates to asset and spatial management, as well as natural resource and environmental stewardship (Diedrich *et al.*, 2022).

The local community relies not only on crop diversification such as red rice, local coffee, onions, and horticultural crops but also on the practice of maintaining ecological balance, including crop rotation, post-harvest fallow periods, and the honoring of soil and water through spiritual rituals such as Ngayu-ayu. Environmental awareness such as changes in temperature and rainfall patterns is addressed by adjusting the types of crops and settlement layouts, reflecting ecological adaptation born from generations of experience. This is also confirmed by the interview with Informant 1 on Wednesday, July 9, 2025, who explained:

The community adjusts its agricultural commodities to new warmer and drier conditions, including expanding horticultural and coffee crops.

Based on the above interview, it is concluded that ecological sustainability and climate adaptation in Sembalun are achieved not merely through modern technological intervention, but rather through the integration of local knowledge, custom, and cultural values in agroforestry management. Agroforestry in Sembalun is more than a farming technique; it is a living system that unites food production with spirituality, ecological wisdom, and communal social structure. Although facing modern challenges such as the use of chemical fertilizers traditional practices remain a vital foundation for maintaining food security and ecosystem health. This is further validated by Subject 4's interview on Thursday, July 17, 2025:

Now everything garlic and other crops relies on chemicals. In the past, we grew garlic without any chemicals, just by basic practices, and it turned out well. Now it has changed, as most Sembalun houses are roofed with zinc, whereas previously they used rerê or alang-alang; so many changes have occurred.

From Subject 4's interview, it is apparent that modern interventions like chemical fertilizers have begun to enter and pose a challenge to the sustainability of traditional, more environmentally friendly practices. Because of this, indigenous agroforestry can serve as a culturally-rooted model of resilience able to survive and adapt amid climate crises. Traditional farming systems often hold important insights for sustainable climate adaptation, although modern interventions can either support or disrupt these systems depending on their context and implementation (Singh and Singh, 2017).

The traditional land management system in Sembalun can offer a rational customary solution, involving crop rotation and the use of subak alas irrigation. This system is effective in maintaining soil fertility and improving water quality. According to survey results, the majority of respondents support these techniques, which aligns with the theory presented in this study, highlighting the importance of land management for climate change mitigation.

The influence of government policy and modernization on customary practices

The local government, together with the customary institutions of Sembalun Bumbung, has undertaken various initiatives to preserve the local culture through revitalization programs, legal protection,

and designation as a cultural heritage area. These policies aim to maintain the sustainability of historical values, social systems, and customary practices so that they are preserved amid the current of modernization. Revitalization has been conducted by ensuring the preservation of ancestral forms, procedures, and symbols while also maintaining supporting infrastructure suitable for customary activities. Government support includes budgeting, regulation, and coordination with traditional leaders to ensure that the entire preservation process aligns with local wisdom. As stated by a traditional figure in an interview with Informant 3 regarding the structure of the customary institution in Sembalun, on Wednesday, July 9, 2025:

What is damaged is renovated, but the traditional aspects are maintained.

Based on the interview with Informant 3, designation as a cultural heritage site does not merely protect the physical aspects of heritage; it also strengthens its role as a center for customary activities and a space for social interaction that forms the collective identity of the Sembalun Bumbung community. Based on fundamental issues and various implemented policy regulations, survey data show that community responses to government policies vary, with some feeling that the policies have not adequately accommodated the needs of the indigenous community. This aligns with findings identified in the proposal, which point out weaknesses in spatial planning policies that have not fully protected the rights of indigenous communities.



Figure 8: (a) 2017 traditional village revitalization monument; (b) Sembalun Tourism; Object Development Assistance; and (c) sembalun traditional ball cultural heritage site.

Modernization within customary practices has brought about a marked contrast between current and past agricultural patterns in Sembalun, as explained in an interview on July 8, 2025, with the Ketua Adat as Informant 1:

Because vegetables yield more today we harvest, tomorrow we plant carrots. The rotation is quick.

Based on this interview, the character of modernization in customary practice has shifted from red rice to many other crops with shorter and more lucrative growing cycles. In the past, red rice was the primary crop as well as the staple food for the community. The process of cultivating red rice adhered strictly to customary rules and took a considerable amount of time, with about eight months in the field and an additional month before rice could be brought home. Consistent with the findings of the research questionnaire, the main challenges in maintaining agroforestry in Sembalun are the pressures from tourism and youth migration. The majority of respondents acknowledge that youth migration and tourism pressures pose the primary threats to the sustainability of the agroforestry system, as many young people from Sembalun now prefer working in the more economically rewarding tourism sector.

Social solidarity and mutual cooperation in indigenous communities

Social solidarity and gotong-royong (mutual cooperation) are fundamental pillars in both agroforestry practices and the day-to-day life of the indigenous community in Sembalun. Gotong-royong serves as an essential tool to strengthen local-level social solidarity, reflected in the practice of mutual assistance among residents, which fosters a sense of togetherness and upholds the moral values within the community (Eng et al., 2023). This value is manifested in collective activities such as begawe, where all community members contribute. Personal events, like children's circumcision ceremonies and the Ngayu-ayu ritual, activate voluntary communal help. The effectiveness of solidarity depends on how community members uphold and respond to each value embedded in gotong-royong within their environment (Raya et al., 2023). This is supported by an interview with Subject 3 on Wednesday, July 13, 2025, who stated:

Here, our social gotong-royong, for example in pelungguh pesta events, is like this: Everyone comes bringing coconuts, usually two each, sometimes four; women bring sugar, rice, and cooking oil everyone in the adat community, whoever they are; while men bring coconuts and wood. In the evening, we each contribute money, so even if someone is poor, for a child's circumcision, the celebration is possible sometimes ending up with a ton or two of rice, or at least half a ton, all because of our gotong-royong system.

Based on the interview, it can be concluded that the social system in Sembalun still highly upholds the value of mutual cooperation, especially in customary activities such as circumcision and Ngayu-ayu. The entire community participates, regardless of social or economic status. Women typically bring sugar, rice, and oil, while men bring coconuts or wood. These contributions are made voluntarily, so even families of limited means can hold celebrations with full community support. Through this system of gotong-royong, hosts receive significant assistance in both food and financial support, thereby lightening the financial burden of events. There are no wage systems in these community activities; important roles, such as pemangku adat, are also performed voluntarily to maintain order and tradition. All forms of collective work illustrate that food security and the customary social system are inseparable, as both are rooted in the spirit of togetherness, collective responsibility, and reverence for ancestral values.

Challenges and opportunities for preserving indigenous agroforestry

Modernization, urbanization, and changes in institutional values have weakened the role of the customary system (Anafo *et al.*, 2023). Extreme temperature shifts, loss of stable seasons, and increasing dependence on chemical fertilizers and pesticides have gradually replaced once more natural traditional agricultural practices. This is supported by an interview with Subject 2 on Monday, July 12, 2025, who expressed:

Firstly, the weather is becoming more extreme, and with garlic and other crops in Sembalun, everything now depends on chemicals. We used to grow garlic without chemicals, just basic methods, and it was good back then.

From the interview with Subject 2 on Monday, July 12, 2025, it can be concluded that there has been a significant transformation in agricultural practice in Sembalun as a result of climate change and modernization. Increasingly extreme weather and reliance on agricultural chemicals such as pesticides and fertilizers are the primary factors distinguishing current practices from the past. In the past, agriculture was carried out more naturally, without chemical inputs, whereas now, crops such as garlic are highly dependent on chemicals to grow successfully. This reflects the weakening of traditional

agricultural systems and the role of customary institutions in maintaining sustainable practices. In addition to climate and weather dynamics, elements of customary structure such as the penuntu and pemangku have started losing their influence, as not all successors carry out their roles in accordance with ancestral traditions (24). This indicates a generational shift, in which customary institutions are no longer viewed as the main source of social authority, leading to the neglect of some customary rules. This is also supported by the following interview with Subject 2 on Monday, July 12, 2025:

This is starting to erode, even though it still exists now, but it's starting to erode. Why is that? Sometimes the penuntu passes away, sometimes there is no rule; we always start from the penuntu, but some pemangku don't always do things as they should.

From this interview with Subject 2, it is concluded that there has been a decline in the function and influence of customary institutions in Sembalun, especially in the roles of figures such as the penuntu and pemangku. The generational transition, which does not fully continue roles according to ancestral patterns, has resulted in the declining authority of customary institutions in community social life. When regeneration is not maintained, or when customary leaders no longer fulfill their duties appropriately, some customary rules are neglected, reflecting a shift in social values and the encroachment of modern systems over traditional roles.

Challenges emerging from questionnaire data analysis show that, in Sembalun's agricultural system, most respondents agree that conflicts between the indigenous community and external parties often occur, particularly regarding land management and spatial policy. This aligns with interviews indicating that land tenure conflicts and unclear land rights are frequent sources of tension. Despite these challenges, opportunities for preservation remain open. Local ecological awareness can be strengthened in collective customary practices. The legal recognition of customary institutions, reinforced through notarial deeds and acknowledgment from the Ministry of Law and Human Rights (Kemenkumham), shows that the community endeavors to adapt to the modern legal system without abandoning its cultural roots. In an interview on Tuesday, July 8, 2025, the Ketua Adat as Informant 1 explained:

If it was ratified in the past, it was already legitimate, and ever since I succeeded my elder brother, it has been legitimate according to custom, the ancestors, and the community. But only after I took office did we draw up the notarial deed and get recognition from Kemenkumham.

Based on the interview with Informant 1, it can be concluded that although customary institutions face many challenges, opportunities for preservation are still wide open. The community demonstrates adaptive efforts by integrating customary values into the modern legal system through the legalization of customary institutions, such as the creation of notarial deeds and recognition by Kemenkumham. This step reflects an awareness to maintain ancestral heritage while simultaneously adapting to contemporary needs, without neglecting the legitimacy of traditions that have been acknowledged by the community through generations. Additionally, social solidarity, gotong-royong, and spiritual rituals such as Ngayu-ayu remain alive as the foundations for sustainability. With inclusive policy support and youth involvement, Sembalun's indigenous agroforestry holds great potential as a model for food security and cultural preservation that adapts to contemporary challenges.

Conclusions and Recommendations

This study demonstrates that the Sembalun Bumbung indigenous community has a long history dating back to the 8th century CE, with a cultural identity shaped by religion, kingdoms, and Islam while maintaining its traditional roots. Customary institutions (krama adat) play a crucial role in safeguarding ancestral heritage, regulating community life, and reinforcing social solidarity. The indigenous agroforestry system, particularly the cultivation of red rice, provides not only agronomic value but also spiritual significance, guided by customary rules and rituals such as Ngayu-ayu, illustrating the integration of ecology, culture, and food security. Gender-based labor is balanced, with men leading rituals and initial production while women contribute actively in post-harvest and social activities. Food security is strengthened through collective bale lumbung, symbolizing solidarity and strategic reserves. Despite challenges such as modernization, youth migration, and weakening customary leadership regeneration, the community continues to adapt and sustain its traditional practices, including through the formal recognition

of customary institutions. These findings highlight the importance of supporting indigenous agroforestry systems and integrating local wisdom into policy and practice to enhance sustainable food security, ecological resilience, and community cohesion.

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Novelty Statement

This study offers a novel perspective by conceptualizing indigenous agroforestry not merely as an ecological land-use system but as a holistic knowledge framework integrating culture, spirituality, customary institutions, and social solidarity in sustaining food security. Through the Sembalun Bumbung case, it highlights how local wisdom and spiritual rituals function as core mechanisms for adaptive and sustainable agroforestry governance.

Author's Contribution

The authors' contributions to this study are as follows. Sumitro coordinated the research team, designed the ethnographic methodology, conducted in-depth interviews with traditional leaders, analyzed socio-cultural data, prepared progress and final reports, and wrote the journal article for Forest Policy and Economics. Risma Ade Aryati conducted participatory observation, participated in mapping agroforestry areas, and carried out policy document analysis. Kormil Saputra facilitated focus group discussions (FGDs) with the community, documented local wisdom, analyzed power relations in forest management, and conducted geographic analysis of agroforestry product value chains.

Generative AI and AI-assisted technology statement

The authors declare that no generative AI or AI-assisted technology was used in the preparation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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