



Integration of Traditional Ecological Knowledge and Community-Based Forest Resource Utilization Practices in Central South Timor Regency

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Abstract

Forests in Indonesia are under significant pressure due to deforestation and degradation resulting from human activities. However, in several areas, traditional practices of forest utilization based on local knowledge have proven capable of maintaining ecosystem sustainability. This study aims to investigate the practices of forest resource utilization and the traditional knowledge of communities regarding forests and ecosystems, as part of their local knowledge system in South Central Timor Regency. This study uses a case study strategy on members of the social forestry group for forest farmers, with a population of 1,149 people and a sample of 20% of the population ($n = 239$). Data were obtained through in-depth interviews, field observations, focus group discussions, and documentation, then analyzed triangulatively to ensure the validity of the findings. The study's results show that communities utilize forest resources selectively, using traditional tools and adhering to customary rules that serve to limit excessive exploitation. Traditional ecological knowledge regarding the role of trees in maintaining water sources, preventing erosion, and maintaining environmental balance serves as a normative guideline that directly influences harvesting decisions and regulates utilization intensity. These findings confirm that traditional knowledge plays a crucial role not only as a basis for ecological ethics but also as social capital and an informal governance mechanism that strengthens sustainable community-based forest management systems.

Keywords: utilization practices, forest resources, traditional knowledge, ecosystem sustainability

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Introduction

The sustainability of tropical forests has become a crucial subject and a central issue in scientific discussions and public policy, particularly in an era of global environmental pressures and climate change (Shrestha et al., 2024). Tropical forests not only harbor biodiversity and store carbon but also support ecosystems and provide food sources, medicines, and raw materials that are vital to communities in many developing countries (Lubega et al., 2022). Dako et al. (2018) note that forests are home to a variety of potential resources, including timber and non-timber forest products, which humans can optimally and sustainably utilize. In Indonesia, the dynamics of land conversion, exploitation pressures, and conflicts over forest ownership are becoming increasingly apparent, meaning that conventional approaches often fail to strike a balance between utilization and conservation (Padmaningrum et al., 2024). The same thing happened in South Central Timor Regency, with a forest area of 95,728.20 ha. Anthropogenic actions, such as forest encroachment, illegal logging, illegal grazing, and forest fires, have caused damage to the forest (Dako et al., 2019). Despite forest destruction in South Central Timor Regency, the dominance

of the Dawan tribe has not compromised local wisdom and traditional knowledge, which remain intact and can be integrated into forest management. This approach has proven successful in several places in the region. This conclusion is reinforced by Mengie and Szemethy (2025), who state that the implications of this failure draw attention to the integration of local wisdom and traditional knowledge as a strategy to strengthen the basis for sustainable management.

The unique values of local wisdom and traditional ecological knowledge in South Central Timor Regency, including *banu* and *nais kio*, are quite effective in forest management and minimizing forest damage. *Banu*, as customary law/local wisdom, prohibits various activities related to natural resources (flora, fauna, and forests) that are destructive. Similarly, *nais kio*, which traditional leaders prohibit from being disturbed or used carelessly, serve to maintain the integrity of the forest. Danial et al. (2025) note that the traditional ecological knowledge system of the Tolaki people in Southeast Sulawesi reflects a sophisticated and time-tested approach to forest management, combining a deep ecological understanding with sustainable resource use practices. Integrated conservation mechanisms, including rotational land use systems, ritual practices, and recognition

of sacred sites, create an effective traditional conservation strategy that has successfully preserved forest resources for generations. However, although traditional ecological knowledge is widely acknowledged in conservation discourse, its direct influence on concrete forest utilization practices and local management decisions remains insufficiently examined. Most studies discuss traditional ecological knowledge normatively, with limited analysis of how it regulates harvesting behavior and extraction intensity.

Nevertheless, there are significant differences between research findings and field practices regarding traditional ecological knowledge (community perceptions of forests and ecosystems) that can influence and shape patterns of forest resource use, particularly in South Central Timor Regency. Many studies have linked traditional ecological knowledge to the quality of ecosystem services and sustainable forest use. (Khosravi Mashizi & Escobedo, 2025). Another perspective, a study of enterprises dependent on non-timber forest products, assesses the institutional and economic sustainability of these enterprises (Harbi et al., 2023). Research investigating the direct empirical relationship between traditional ecological knowledge and forest resource utilization practices in local communities, conducted using in-depth case study methodology, is still scarce. Research on the utilization of non-timber forest products in rural communities reveals that the flow of benefits depends on socioeconomic motivations (Luswaga, 2023). From another perspective, research on the utilization of non-timber forest products in communities reveals that the practice of harvesting these products is also prone to overexploitation in the absence of local regulations (Dako et al., 2019; Thammanu et al., 2021). Empirical studies explicitly analyzing the link between traditional ecological knowledge and forest use practices in the context of forest management are still limited, particularly in the South Central Timor Regency. This gap is significant because understanding how ecological knowledge shapes practices is crucial for strengthening community-based forest

management policies.

To address this gap, this study employs a conceptual framework grounded in social-ecological systems and community-based governance principles. This study utilizes traditional ecological knowledge as a form of local knowledge capital that influences social norms and decisions related to utilization (Mai et al., 2025). In addition, joint production studies between timber and non-timber utilization (timber and non-wood co-production) emphasize the importance of considering access rights, ownership, and local institutions (Sheppard et al., 2020). This study employs a case study approach to investigate the relationship between traditional ecological knowledge and forest resource utilization practices, as informed by customary rules, norms, and local regulations that informally balance direct benefits and conservation.

The objective of this study is to investigate how traditional knowledge about forests and ecosystems, as a local knowledge system among forest farmer groups, influences how forest resources are used. This study focuses on the practical models of how traditional ecological knowledge and forest resource utilization practices are integrated within forest communities, with informal social regulations serving as the primary link. The novelty of this research lies in using an in-depth case study to investigate the relationship between traditional ecological knowledge and forest resource utilization in South Central Timor Regency, an area that has not been widely studied. It is hoped that these findings will enrich the literature on community-based forest management and provide a practical basis for policies that are more adapted to local wisdom.

Methods

Research time and location This research was conducted over a period of five months from June to October 2025 in 15 Forest Farmers Groups (FFG) in South Central Timor Regency (Figure 1). The research location focused on forest farmer groups that had obtained social forestry

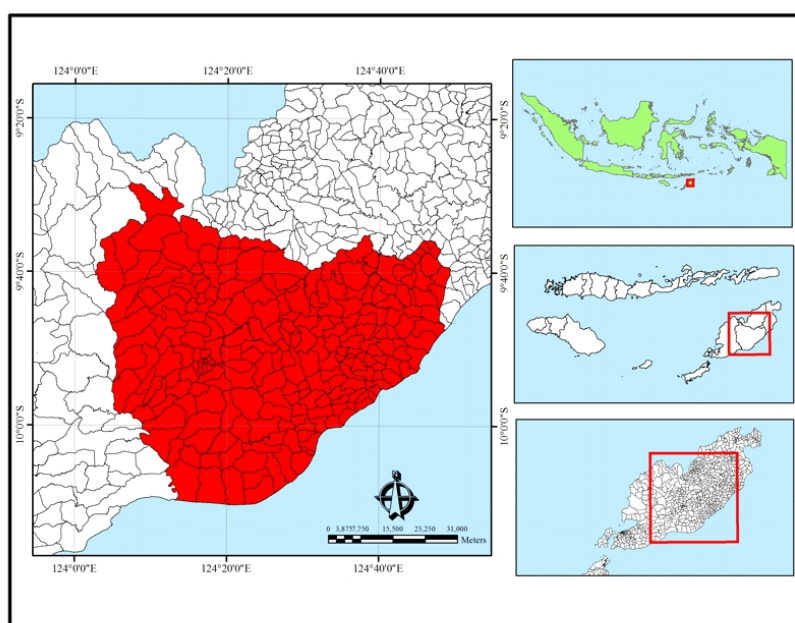


Figure 1 Study location.

permits/approval from the Ministry of Forestry of the Republic of Indonesia. The Forest Farmers Groups include Olitataf FFG in Bikeknenno Village, Haumen FFG in Oelbubuk Village, Berdikari FFG in Binaus Village, Manekto FFG in Loli Village, Meolanan FFG in Puna Village, Paloil Pa Ma Nifu FFG in Konbaki Village, Olitataf FFG in Nule Village, Ora Etlabora FFG in Noenbila Village, Seati 2 FFG in SoE Village, Taheun Pah FFG in Fatukoto Village, Tunas Baru FFG in Netpala Village, Haufomeni FFG in SoE Village, Enonapi FFG in Enonapi Village, Setia FFG in Oelekam Village, and Bersaudara FFG in Eonbesi Village. The selection of these locations was based on their relevance to the research objectives, specifically to explore the practices of forest resource utilization and the community's traditional knowledge regarding forests and ecosystems.

Research tools, materials, and variables The research equipment and materials used in this study included voice recorders, cameras, GPS devices, compasses, writing instruments, tally sheets, questionnaires, and laptops for data transcription and analysis. The main variables in this study were, first, practices in the utilization of forest resources, and second, the community's traditional knowledge of forests and ecosystems. For the variable of forest resource utilization practices, the collected data included the types of forest resources, the amount of utilization, harvesting methods, the purpose of utilization, and changes in forest resource utilization practices. Meanwhile, for the variable of traditional community knowledge of forests and ecosystems, the data collected and gathered included local knowledge about the classification and naming of flora and fauna, the importance of trees in providing water, the role of trees for living creatures and the environment, natural indicators in relation to climatology (climate, weather), and the value of local wisdom in forest and natural resource management.

Population and sample In this study, the data source consisted of all members from 15 FFG in TTS Regency who had obtained a decree of approval for social forestry from the Ministry of Forestry, totaling 1,194 individuals. Considering the time, cost and effort involved, the sample taken was 20%

of the population, resulting in a total of 239 respondents, comprising 165 men and 74 women (Table 1). The sample taken is one of the common choices used in social research, especially qualitative studies, to obtain sufficiently representative data. Sampling techniques were carried out proportionally within each farmer group, ensuring a minimum representation of 30% women (Anggraini et al., 2024). Women must be involved in every activity, and female representation in strategic positions and decision-making is a new hope in the global environment. This strategy enables the collected data to more comprehensively and fairly reflect the conditions of the population. For documents, only locally verified sources, such as customary regulations, land use maps, and activities in social forestry approval decrees, are included in the analysis. These criteria ensure that all information used truly represents the empirical experiences of the community in the field.

Research method This study employs a case study method with a qualitative approach to explore the relationship between traditional community knowledge about forests and ecosystems and the practice of forest resource utilization. The case study method is very helpful for in-depth exploration of a case (Yin, 2018). The case study method is considered adequate for exploring the complexity of the relationship between humans and the environment, as well as identifying the social meaning behind forest utilization practices traditional knowledge of forests and ecosystems. This method also enables researchers to study phenomena in a contextualized manner in real-life settings, relating them to social and ecological dynamics within forest communities (Crowe et al., 2011).

The data used in this study are primary and secondary. Primary data is the main source of data for this study, obtained directly through participatory observation, in-depth interviews, focus group discussions, and field documentation. Secondary data refers to supporting information obtained from scientific literature and local documents, used as comparative material to strengthen the theoretical framework. In accordance with the principles of contextual qualitative research, the use of primary data enables the

Table 1 Research population and sample

Forest farmers group	Population		Total	Respondent sample	Respondent gender	
	M	F			M	F
Oliftataf FFG, Bikeknenno	111	19	130	26	17	9
Haumen FFG	143	32	175	35	25	10
Berdikari FFG	12	18	30	6	4	2
Manekto FFG	115	44	159	32	23	9
Meolanan FFG	78	18	96	19	13	6
Paloil Pa Ma Nifu FFG	130	13	143	28	20	8
Oliftataf FFG, Nule	76	16	92	18	13	5
Ora Et Labora FFG	42	18	60	12	8	4
Seati II FFG	24	6	30	6	4	2
Taheun Pah FFG	49	4	53	11	8	3
Tunas Baru FFG	44	9	53	11	8	3
Haufomeni FFG	44	5	49	10	7	3
Enonapi FFG	37	9	46	9	6	3
Setia FFG	32	0	32	7	5	2
Bersaudara FFG	35	11	46	9	6	3
Total	972	222	1194	239	166	73

analysis of the community's understanding of traditional values and practices related to forest resource utilization (Denzin & Lincoln, 2021). All data collection processes were conducted in accordance with social research ethics, which include obtaining participant consent and maintaining the confidentiality of their information.

Data collection techniques Data was collected through in-depth interviews, focus group discussions, participatory observation, and analysis of field documents. In-depth interviews were conducted to explore local communities' understanding of forests and ecosystems, as well as the various forms of forest resource utilization. In-depth interviews were semi-structured and included questions on the type and intensity of forest resource utilization, harvesting methods used, customary rules or social norms governing utilization, community understanding of forest ecological functions, and changes in practices following the social forestry program. Focus group discussions were conducted to validate and expand on the findings of individual interviews, with the discussions centered on collective perceptions of customary prohibitions, social sanction mechanisms, traditional seasonal indicators, and the relationship between ecological knowledge and forest utilization decisions. Direct observations were conducted in the field to document actual practices of forest resource utilization and the social norms that govern them. In participatory observation, practices refer to the actual actions of communities in utilizing forest resources, such as firewood and techniques for harvesting non-timber forest products, tree species, and harvest locations (selective or not), the use of traditional tools, the frequency and timing of harvesting, and the treatment of areas considered sacred or protected. Meanwhile, social norms include compliance with customary prohibitions (e.g., the Banu system), social sanction mechanisms for violations, the role of customary leaders in regulating utilization, the distribution of access and utilization rights, and the practice of deliberation in forest-related decision-making. Document analysis involves examining community records and local regulations related to forest use (Bowen, 2009).

Data analysis The data obtained were analyzed qualitatively by describing the data in the form of sentences that were systematically organized, complete, and detailed in accordance with the specified theme (Yeny et al., 2016). To identify the main themes related to forest resource use and traditional community knowledge about forests and ecosystems, data analysis was conducted thematically through open coding, axial coding, and selective coding stages. Thematic analysis techniques enable the systematic categorization of qualitative data, allowing for the discovery of patterns and relationships between themes (Korstjens & Moser, 2018).

Documentation data were analyzed using a systematic document analysis approach to understand the social meanings, values, and policies contained within the documents (Bowen, 2009). This study employed a triangulation strategy, combining methods, sources, and theories to enhance the validity and credibility of its results

(Carter et al. 2014). Triangulation was also used to assess the convergence of results between sources and methods (interviews, observations, and documents) (Donkoh & Mensah, 2023).

This technique has been proven to improve data reliability by enhancing the credibility, dependability, and confirmability of research (Korstjens & Moser, 2018). In practice, field observations and documentation are used to verify interview findings, which are then compared with relevant supporting literature. The principle of qualitative validity emphasizes the iterative examination and researcher reflexivity. Analysis is conducted repeatedly and interactively, from data collection to interpretation of results. This method of analysis ensures that the meanings generated remain grounded in the views of the local community, the primary subjects of the research (Denzin & Lincoln, 2021).

Results

Practices in forest resources utilization *Types of forest resources* The results of the study show that 239 respondents demonstrated significant dependence on forest resources, with varying practices in terms of type, volume, method, and frequency of harvesting. Most respondents showed a dependence mainly on non-timber forest resources, such as honey, water, mushrooms, and wildlife, including birds, as well as timber forest products, especially firewood. Based on the study's results, 100% of respondents regularly use firewood for cooking and heating their homes. The data obtained shows that 100% of respondents use water for cooking and washing. In addition, other respondents utilize non-timber forest products, such as honey (10.3%), mushrooms (6.8%), rattan (1%), forest betel (0.93%), ant nests (0.60%), and tamarind (1.5%) to meet household needs and for commercial purposes. Other respondents (1.4%) utilized game in the form of birds and medicinal plants (4.4%) for consumption and commercial purposes.

Amount of forest resource utilization The type of forest resource determines how much is used. The study's results indicate that the average amount of firewood used per household is 47 bundles week⁻¹, equivalent to approximately 192336 bundles year⁻¹. Meanwhile, the average amount of water used per household is 150–175 liters day⁻¹, or approximately 54,750–58,800 liters year⁻¹. Firewood is the primary source of energy for cooking and heating and is typically used daily. The fact that firewood and water are essential shows that both are critical. The use of medicinal plants, mushrooms, and honey is more seasonal, occurring only once a year. In addition, 10.2% of respondents reported harvesting between 6.5 and 144 liters of honey season⁻¹, with a total of 1,195 liters (an average of 47.8 liters season⁻¹), and 6.8% reported harvesting between 2 and 10 kilograms of mushrooms per season/household. There were 1.4% of respondents who encountered wild animals, such as birds, while searching for wood or grazing cattle in groups of 12 animals, and this was not a routine occurrence but rather happened once every 34 months. The community's dependence on forest resources was very high in meeting their daily needs, including energy, food, and medicine.

Harvesting method Traditional harvesting methods, using simple tools, are the most commonly employed to utilize forest resources. The study's results show that 100% of respondents use machetes as their primary tool for collecting firewood, whether by cutting dry branches, gathering fallen wood, or cutting small logs. For water, the harvesting method used is drawing water with jerry cans or buckets. For honey, the traditional method involves using smoke, rope, knives, machetes, and simple containers, such as buckets.

Additionally, air rifles or slingshots are used for hunting birds, while knives, machetes, sacks, or buckets are used for gathering mushrooms and medicinal plants. This method demonstrates that harvesting technology remains relatively simple, yet it can still pose safety and efficiency issues. Traditional harvesting practices with low technology often increase the risk of degradation if not regulated.

Objectives of forest resource utilization The utilization of forest resources essentially has two main objectives: household consumption (subsistence) and commercial or economic interests. The results of the study show that the respondents' purpose in utilizing forest resources is to meet their daily needs and increase their family income by 100%. This purpose directly affects the frequency and volume of harvesting. Commercial purposes, for example, encourage the extraction of larger quantities of resources for sale. The results of the study indicate that commercial harvesting behavior appears to be limited to a few non-timber forest products.

Changes in forest resource utilization practices The results of the study show that all respondents (100%) said that utilization practices have not changed since the Social Forestry program began. The community is still utilizing forest resources as they were before. Forest resources are utilized only to meet daily needs and increase family income. Patterns of forest resource utilization are relatively similar among all 15 forest farmer groups participating in the Social Forestry program in South Central Timor Regency. In the context of social forestry, social forestry programs should play a role in raising public awareness of environmental preservation and the importance of conservation efforts. Social forestry programs have successfully reduced the rate of forest degradation through community empowerment and participation approaches. This has shifted the perspective from exploitation to sustainable management. However, communities continue to maintain the utilization practices they have employed for years, even as social forestry is being implemented.

Community traditional knowledge about forests and ecosystems *Classification of flora and fauna name* The results showed that 74% of respondents acquired knowledge about the naming of flora and fauna from their ancestors. In comparison, 17% of respondents were aware of specific morphological characteristics, such as the shape of the stem, leaves, benefits, and properties, while 9% of respondents had no understanding or knowledge about the naming of flora and fauna. This suggests that oral traditions and local wisdom remain the primary sources for ecological classification within communities. This practice aligns with

ethnobiological research, which has shown that the naming of local flora and fauna reflects socio-cultural values and environmental functions (Iskandar, 2017). Thus, the naming pattern of flora and fauna is not merely a matter of terminology but also a conservation tool that emphasizes the interconnectedness of humans and the environment.

Ecological understanding related to springs, living creatures and the environment The results of the study show that 79% of respondents emphasized the importance of trees in maintaining the sustainability of springs and as a source of life for living creatures. Meanwhile, 21% of respondents who were uneducated did not understand or were unaware of the critical role trees play in maintaining water sources. In terms of their function for living creatures, around 77% of respondents stated that trees provide oxygen, habitat, shelter, and food sources for humans and animals. In comparison, 23% did not know or understand their functions. The results show that local communities continue to view forest ecosystems as shared living spaces (shared habitats) that support the survival of all living creatures.

Meanwhile, ecological understanding is closely tied to the environment, with 78% of respondents emphasizing that trees play a crucial role in maintaining environmental stability by preventing erosion, landslides, and flooding, as well as cooling the air. These results suggest that traditional communities have a collective awareness that forests are a life-support system. Thus, the environmental understanding of indigenous peoples demonstrates the integration between biophysical functions and cultural values, proving that conservation based on local wisdom is still relevant and practical. Meanwhile, 22% of respondents had a poor understanding of ecological knowledge related to the environment, and these respondents were predominantly those who had not attended school. School education can actually provide individuals with an understanding of what they learn, including ecological knowledge. This type of environmental awareness suggests that traditional ecological knowledge serves as a form of management knowledge that integrates biophysical functions and cultural values.

Natural indicators (weather, seasons, and availability of natural resources) The results of the study show that 74% of respondents often use the sound of the Kolton bird (Dawan language) as a sign of the arrival of the rainy season; 100% of respondents see natural signs such as clouds, thunder, and lightning; 5% of respondents feel an increase in temperature; and 11% of respondents do not know the natural signs that indicate the arrival of the rainy season. A total of 72% of respondents considered the signs of the dry season to be the flowering of *turis* and *dadap* trees, cold temperatures at night, and falling leaves or changes in color. In comparison, 28% did not recognize the signs of the dry season and considered it to be hot. This indicates that the community remains heavily reliant on natural bioindicators to assess the impact of climate change and seasonal shifts. Thus, the use of natural indicators by communities in research reflects cultural attachment to ecological dynamics, while also serving as a risk mitigation strategy based on empirical experience.

Local wisdom The results of the study show that most respondents (74%) stated that it is forbidden to cut down trees in locations considered sacred or of spiritual value. Some groups showed a high level of compliance (such as Oliftataf FFG in Bikekneno Village, where 92.3% stated that there was a prohibition on cutting down trees in areas considered sacred). The function of these customary rules is similar to the concept of 'sacred groves', which serve as spiritually and socially based conservation zones.

In the context of local wisdom in protecting and preserving forests and other social life throughout forest farming groups, especially respondents aged over 50 years old, they have a deep understanding of the local context of Banu/Banu Naik/Banu Turun; Nais Kio; Pahe Kulin Pahe Nakan; Oele'matan, Hune'ba'an; Haut nam nasimma makona, Honot nam nais/Klai; and Mansinan-Muit-Nasi/Na Bua. Local concepts: *Banu/Banu Naik/Banu Turun*. This is a customary law/local wisdom that prohibits various activities related to natural resources (flora, fauna, and forests) when implemented. *Banu Naik* indicates when activities are not permitted (open prohibition), while *Banu Turun* indicates when the ban is lifted, allowing activities to resume. This is the indigenous community's way of regulating when and how they can use the forest/natural resources, ensuring they are not damaged. The local concept of *Nais Kio* means that the forest is forbidden by traditional leaders to be disturbed, used, or exploited indiscriminately. Its function is to preserve the forest, protect animals, trees, flora, and fauna.

On the other hand, *pahe kulin pahe nakan* is a local term for areas of land/forest that are differentiated based on their function/benefit. For example, some places are used for food cultivation, while others are protected. Meanwhile, *Oele'matan* and *Hune'ba'an* are specific zones within customary management areas that indicate the type of function of the region or location in terms of forest use and conservation. The concept of *Haut nam nasimma makona*, *honot nam nais/klai* is a local expression that describes a dense, lush, undisturbed forest, which is an ideal condition that is maintained by the community through customary rules and prohibitions. The Dawan tribe community also recognizes the concept of local Mansinan-Muit-Nasi/na bua, which is the concept of a triangle of life between humans, livestock, and forests. This concept also shows that forests are not foreign entities; humans and livestock depend on them, and forests need to be maintained so that all three remain alive and balanced.

In the context of local wisdom related to forest management, some respondents (74%) emphasized the prohibition of logging in forests considered sacred or having spiritual significance. In comparison, 26% were unaware of such local wisdom practices. Local wisdom in forest management suggests that communities continue to adhere firmly to the forest prohibition system as a socio-cultural mechanism for maintaining forest sustainability. In some cases, violations of the prohibition (*Banu*: Dawan language) are believed to bring about dire consequences such as illness, insanity, or even death. The penalty imposed on community members who violate this prohibition is a large pig, 50 kg of rice, and one bottle of "sopi" (a traditional alcoholic beverage). These items are then cooked and shared among

the community. Before the ingredients are processed, the community leaders (traditional elders) perform a ritual to ask *Uis Pah* for forgiveness for the violations that have been committed. Prohibition on tree felling both within the area and in protected forests as a manifestation of preserving the forest and ensuring it continues to provide benefits for all living creatures.

Thus, local wisdom developed within communities is not only a mythological heritage but also an ecological conservation strategy that has proven effective in maintaining balance between humans, nature, and the spiritual dimension. Traditional ecological knowledge acts as a social regulatory mechanism that can curb excessive exploitation of ecosystems.

Discussion

The results of the study show that communities in 15 Forest FFG, which have been granted social forestry permits or approvals from the Ministry of Forestry in South Central Timor Regency, are highly dependent on forest resources for their basic needs and economic benefits. All respondents use firewood and water from the forest for household needs. On the other hand, some people rely on non-timber forest products, such as mushrooms, honey, and medicinal plants, to earn additional income. Diniyati and Achmad (2015) stated that communities living around forests are highly dependent on non-timber forest products as a source of income and food. Adella et al. (2024) noted that although the economic contribution of non-timber forest products is relatively small compared to firewood, this contribution is significant in diversifying income sources for forest village communities. These differences in utilization demonstrate the existence of family economic adaptation strategies in forest communities to meet their living needs (Kasoki et al., 2025). This pattern is consistent with research showing that tropical communities living near forests use them as economic protection and social-ecological buffers, especially amid limited access to formal energy and resources (Shresta et al., 2024; Kasoki et al., 2025). This dependence confirms that forests not only play an ecological role but are also an essential part of the social system that supports the rural household economy (Ouedraogo et al., 2025). However, the use of firewood for daily needs indicates that the ecosystem is under constant pressure if there are no mutually agreed-upon regulations.

Differences between forest farmer groups in terms of honey harvesting frequency, types of non-timber forest products utilized, and the intensity of their utilization reflect variations in access, technical capabilities, and socio-economic strength at the local level. In this context, harvesting methods that utilize traditional tools, such as machetes, ropes, and simple containers, not only demonstrate technological limitations but also showcase sustainable practices that are inexpensive and preserve traditional ecological wisdom (Derebe & Alemu, 2023). The use of traditional tools in harvesting non-timber forest products in South Central Timor Regency is also carried out in several places in Indonesia and in various other countries. These findings support the idea that social norms limiting extraction intensity can support sustainability with low technological

efficiency (Gunawan et al., 2022). Diniyati and Achmad (2015) stated that conventional approaches are still used to harvest forest products in several places in Indonesia, such as Karyabakti Village in Parungponteng District, Tasikmalaya. Globally, Angelsen et al. (2014) highlighted that rural communities in Africa and Asia tend to use simple harvesting techniques due to limited capital. However, these methods are prone to causing degradation if practiced excessively. Traditional, low-tech harvesting practices often increase the risk of degradation if not regulated. In terms of traditional knowledge, the community has a strong understanding of the ecological role of forests and their relationship with ecosystem balance. The majority of respondents are aware that trees play a crucial role in maintaining water availability, preventing erosion, and stabilizing the microclimate. Social mechanisms and local languages pass down this type of traditional ecological knowledge. Khosravi Mashizi and Escobendo (2025) state that conventional environmental knowledge integrates cultural, ecological, and spiritual elements into decision-making processes, making it an effective system for managing ecosystem services. The use of natural bioindicators, such as the sounds of Kolton birds, clouds, thunder, and lightning, to determine the rainy season in this study is a practical example of the application of local ecological knowledge. The use of traditional ecological signs to determine seasonal changes is known as traditional climate knowledge, which has been shown to have a high degree of accuracy in various local communities as a form of adaptation to climate change (Zvobgo et al., 2023). Indigenous communities in Africa and South Asia interpret microclimate dynamics in a manner that closely resembles this method (Salim et al., 2023). Traditional ecological knowledge, such as this method, forms the basis for ecological adaptation that cannot easily be replaced by modern technology, as it is derived from empirical experience passed down from one generation to the next (Min et al., 2024).

In addition, there are customary prohibitions or sacred areas that must not be damaged, illustrating how spiritual norms have evolved into socially based conservation mechanisms. In South Central Timor Regency, bans in the form of *banu* and *nais kio* are quite effective in protecting forests. *Banu*, as customary law/local wisdom, prohibits various activities that damage forest resources. Likewise, *nais kio* functions to maintain the integrity of the forest. *Banu* and *nais kio* are guidelines for preserving forests, and models like these are applied in several places in Indonesia and other countries with different names. As explained in studies of sacred gardens in Africa and Asia, these mechanisms ensure the sustainability of essential species, protect water sources, and preserve the holy value of the landscape (Sinthumule, 2024). The level of community compliance with customary prohibitions in this study exceeded 70% in most groups, indicating that traditional norms are widely accepted. This condition supports the idea that cultural beliefs can function as informal rules that regulate ecological behavior without the aid of law.

However, the dynamics in the field also show conflicts between conservation efforts and subsistence needs. Some community members continue to engage in intensive

exploitation, especially of firewood and water, due to economic pressures. These pressures are generally related to limited non-forest income sources, the need for children's education and healthcare, socio-cultural needs, and dry season conditions that reduce agricultural productivity. Under these conditions, several respondents acknowledged that access to certain forest products, particularly timber and other economically valuable forest products, tends to increase even within traditionally restricted zones. This situation indicates that violating norms serves as a short-term adaptive strategy rather than a rejection of customary systems, especially when alternative economic options are scarce. Research results from Derebe and Alemu (2023) reveal a similar phenomenon: when financial needs are not met, customary norms are often selectively violated. Therefore, the success of traditional ecological knowledge in maintaining forest sustainability depends on external resources such as access to markets for non-timber forest products, monetary incentives, and institutional assistance. This confirms that integration between formal rules and traditional values is necessary to reinforce each other in the context of Indonesia's social forestry policy (Gunawan et al., 2022). In addition, a significant amount of literature worldwide supports an integrative approach between traditional ecological knowledge and formal policy. Timisgansac et al. (2025) state that the success of community-based conservation in the mountainous regions of Europe depends on recognition of local knowledge systems and community participation in decision-making processes. A participatory management approach that integrates customary mechanisms has proven to yield better results in terms of management performance and economic welfare improvement compared to entirely government-led systems. Forest management and utilization improve when customary mechanisms are combined with governance models. The above statement aligns with the findings of research conducted on 15 social forest farmer groups in South Central Timor Regency, which obtained a decree of approval for social forestry.

The results of the study on these 15 forest farmer groups indicate that communities with higher levels of traditional knowledge tend to employ selective harvesting practices and adhere to customary rules more strictly. Selective harvesting practices involve removing only mature trees or those that have died naturally, avoiding the felling of trees near water sources, limiting the number of trees harvested, and respecting areas designated as sacred or off-limits. In contrast, non-selective harvesting removes resources without regard for the age, location, or ecological role of the trees. Selective methods prioritize natural regeneration and the maintenance of the forest's hydrological functions. Ecologically, these practices help preserve vegetation cover, stabilize soil, and protect water resources, thereby supporting the long-term sustainability of the ecosystem. As a result, increasing local institutional capacity is essential to enable the use of conventional ecological knowledge as a policy tool within a more flexible social forestry framework. Based on research findings, this strengthening can be achieved through several concrete mechanisms, namely, formalizing customary rules such as the *banu* system and protecting

sacred areas in village management plans, involving customary leaders and forest farmer groups in the preparation of annual work plans, strengthening the administrative and monitoring capacity of groups through training in governance and utilization recording, and integrating locally based environmental education that connects customary norms with formal regulations. Alignment of formal and informal rules can be achieved through a co-management mechanism, where social forestry policies recognize customary zoning as part of legal spatial planning and use local norms as the basis for utilization restrictions. This approach not only symbolically recognizes traditional ecological knowledge but also allows it to function operationally within the policy system.

This research conceptually demonstrates that the relationship between traditional ecological knowledge and forest resource utilization practices supports the socio-ecological systems paradigm. This paradigm emphasizes the dynamic interactions between humans and ecosystems that shape contextual management patterns. In the context of this research, traditional ecological knowledge acts as a mechanism linking ecological functions with social norms, social capital, and cultural identity, thereby strengthening pluralistic and adaptive governance when combined with formal policies. However, field findings also indicate that traditional ecological knowledge faces limitations when faced with external pressures, such as increasing household economic needs, market access to economically valuable forest commodities, and seasonal climate variability. In such situations, customary norms can undergo selective renegotiation, indicating that traditional understanding alone is not fully capable of anticipating large-scale structural changes. Therefore, modern scientific knowledge, such as in forest cover monitoring, climate adaptation planning, and rehabilitation techniques, can complement traditional ecological knowledge by providing technical and analytical support that strengthens community adaptive capacity. Integration of the two enables forest governance to be more responsive to contemporary challenges.

Thus, this study strengthens the evidence that forest sustainability in populated areas depends heavily on the ability of policies to accommodate diverse knowledge systems and ensure ecological justice for indigenous and local communities. Future research should explore the long-term impacts of integrating traditional ecological knowledge and forest management policies on forest cover stability and community adaptive capacity. Furthermore, a more in-depth study of the economic potential of non-timber forest products and their contribution to reducing timber exploitation pressure is crucial for understanding livelihood diversification strategies. Comparative research in other regions is also needed to assess the extent to which local mechanisms such as the *banu* system and customary zoning can be replicated or adapted on a broader scale without losing the socio-cultural context.

Conclusion

This study demonstrates that practices for utilizing forest resources and traditional ecological knowledge play complementary roles in maintaining the sustainability of

forest ecosystems. Communities utilize forest products for their livelihoods, but these practices are governed by traditional principles, customary norms, and ecological understandings that limit the intensity of exploitation. Thus, traditional knowledge serves not only as a cultural heritage but also as a normative foundation that shapes sustainability-oriented utilization behavior. Furthermore, formal education does not replace traditional knowledge; rather, it can complement and strengthen communities' capacity to understand increasingly complex environmental dynamics and enhance their ability to adapt to new challenges. The integration of these two knowledge systems strengthens the effectiveness of community-based forest management. Consequently, forest management policies need to explicitly recognize and institutionalize traditional ecological knowledge as part of legitimate governance mechanisms while simultaneously strengthening environmental education and local institutional capacities. This integrative approach is crucial for promoting adaptive, participatory, and sustainable forest governance in the context of evolving socio-ecological changes.

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