Traditional Ecological Knowledge among Madurese Communities: An Integrated Coastal Zone Management Perspective

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Abstract. Traditional Ecological Knowledge (TEK) plays an important role in supporting environmental sustainability through locally developed systems of knowledge and practice. This study examines Madurese TEK as living cultural heritage through the analytical lens of Integrated Coastal Zone Management (ICZM). Although previous studies have documented Madurese agricultural and coastal knowledge separately, limited attention has been given to their interconnections as components of an integrated land–sea socio-ecological system. This study employed a constructivist paradigm and ethnographic approach in Pamekasan, Madura, Indonesia. Data were collected through participant observation, in-depth interviews with 15 informants, and documentation, and analyzed using Spradley's Developmental Research Sequence, comprising domain, taxonomic, componential, and cultural-theme analyzed. The findings identify two interconnected domains of Madurese TEK. Agroecological knowledge is reflected in the *nambhere'-nemor* planting calendar, crop rotation, and interpretation of environmental indicators such as wind, stars, and animal behavior. Coastal ecological knowledge encompasses awareness of ocean currents and fishing seasons, customary restrictions on fishing activities, and the *rokat tasè'* ritual. Cross-domain analyzed reveals three shared ecological principles: environmental observation, seasonal adaptation, and resource regulation. These principles demonstrate that Madurese ecological knowledge operates as an interconnected land–sea knowledge system rather than a collection of isolated practices. The study contributes to Nusantara heritage scholarship by demonstrating that Madurese TEK retains both cultural significance and ecological functions. Through the ICZM lens, local knowledge can provide a culturally grounded basis for understanding relationships among land, sea, livelihoods, and environmental sustainability while supporting intergenerational knowledge transmission and community-based environmental management.

Keywords: Traditional Ecological Knowledge, Madurese, Agroecological Knowledge, Coastal Ecological Knowledge, ICZM.

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1 Introduction

Environmental degradation and climate variability are increasing pressure on communities that depend on natural resources. These challenges require environmental approaches that recognize local knowledge as an important source of ecological understanding. Traditional Ecological Knowledge (TEK) develops through long-term interactions between communities and their environments [1]. It includes knowledge of seasonal cycles, environmental indicators, resource availability, and appropriate patterns of resource use [2]. Previous research has shown that local ecological knowledge can support resource management and community adaptation to environmental change [3]. Such knowledge also reflects cultural values and practices that guide human interactions with nature [4]. TEK should therefore be understood as a knowledge system that can contribute to environmental sustainability.

The relationship between land and sea is particularly important for communities living within coastal environments. Changes in terrestrial environments can influence coastal ecosystems while marine conditions can affect coastal livelihoods and human activities [5]. Agricultural practices depend on soil, water, and seasonal conditions [6]. These factors can also influence coastal ecological conditions through the movement of water and resources [7]. Coastal resources provide food and livelihood opportunities for many communities [8]. Integrated Coastal Zone Management (ICZM) responds to this relationship by promoting the integration of terrestrial and marine environments in coastal management [9]. ICZM therefore provides a relevant analytical lens for examining ecological knowledge that connects land-based and coastal practices.

The Madurese people provide an important context for examining this relationship. Their ecological knowledge has developed through long-term interactions with diverse agricultural and coastal environments. Madurese communities have developed agricultural practices that respond to seasonal variation and relatively dry environmental conditions [10]. Coastal communities have also developed knowledge related to fishing seasons, marine conditions, and resource use [11]. These practices demonstrate that environmental knowledge is closely connected to local livelihoods. They also show that ecological practices emerge from continuous interaction between communities and their surrounding environments [12]. The Madurese context therefore provides an important setting for examining the relationship between terrestrial and coastal ecological knowledge.

Agroecological Knowledge represents an important form of Madurese ecological adaptation. It enables communities to organize agricultural activities according to local environmental conditions. The *nambhere'-nemor* calendar provides knowledge about seasonal agricultural activities [13]. Corn–bean–tobacco rotation contributes to the continued use of agricultural land [14]. Farmers also interpret natural signs such as wind, stars, and animal behavior when making agricultural decisions [11]. These practices support soil fertility and reduce the risks associated with climate variability. Agroecological Knowledge therefore functions as a locally developed strategy for maintaining agricultural productivity under changing environmental conditions.

Coastal Ecological Knowledge provides a parallel system of adaptation within marine environments. It guides communities in determining when and how marine resources should be used. Madurese communities possess knowledge of ocean currents and fishing seasons. They also maintain customary restrictions on fishing activities and practice the *rokat tasè'* ritual [15], [16], [17]. These practices regulate interactions with marine resources and connect resource use with ecological and cultural cycles. Such knowledge can reduce excessive exploitation and support the continued availability of coastal resources. Coastal Ecological Knowledge therefore represents an important mechanism for maintaining sustainable relationships between communities and marine environments.

The relationship between Agroecological Knowledge and Coastal Ecological Knowledge remains insufficiently examined as an integrated system. Existing discussions of Madurese ecological knowledge often focus on particular environments or cultural practices. Agricultural knowledge is frequently examined through farming systems while coastal knowledge is examined through fisheries and marine conservation. This separation can obscure the ecological connections between terrestrial livelihoods and coastal environments. ICZM offers a useful perspective for examining these connections because it emphasizes the integration of land and sea within coastal environmental management [8], [18]. Using ICZM as an analytical lens can therefore provide a clearer understanding of how Madurese TEK connects terrestrial and coastal ecological practices.

This study examines Agroecological Knowledge and Coastal Ecological Knowledge among the Madurese people through the lens of Integrated Coastal Zone Management. The study identifies the forms of traditional knowledge embedded in agricultural and coastal practices. It also examines the ecological functions of these practices in relation to environmental adaptation and resource sustainability. The analyzed focuses on how knowledge of agricultural and marine environments is developed through local experience and maintained through community practices. These findings provide insight into the relationship between land-based and coastal ecological knowledge. The study contributes to the discussion of TEK by showing how Madurese ecological practices can be understood through an integrated land–sea perspective.

2 Method

This study adopted a constructivist paradigm and used an ethnographic approach to examine Madurese Traditional Ecological Knowledge (TEK) in agricultural and coastal environments [19]. Ethnography was selected because ecological knowledge is embedded in everyday practices and shaped by long-term interactions between communities and their environments. The study focused specifically on two domains: Agroecological Knowledge and Coastal Ecological Knowledge. The research was conducted in Madurese communities in Pamekasan, Madura Island, East Java, Indonesia.

Data were collected through participant observation, in-depth interviews with 15 informants, and documentation. These methods enabled the researchers to examine both the practices themselves and the meanings attributed to them by community members.

Informants were purposively selected based on their experience and knowledge of agricultural and coastal practices. The interviews explored seasonal farming practices, crop rotation, environmental indicators, fishing seasons, marine conditions, customary restrictions, and cultural practices related to resource use. Observations were used to document ecological practices in their natural settings. Data triangulation was applied to strengthen the credibility of the findings.

The data were analyzed using the Developmental Research Sequence (DRS) [20]. This approach was used to identify cultural meanings and relationships within the observed ecological practices. The analyzed involved domain, taxonomic, componential, and cultural theme analyzed. Domain analyzed identified Agroecological Knowledge and Coastal Ecological Knowledge as the principal domains. Taxonomic and componential analyses examined the forms and ecological functions within each domain. Cultural theme analyzed then examined the relationship between agricultural and coastal knowledge through the lens of Integrated Coastal Zone Management (ICZM). This analytical process allowed the study to examine how Madurese TEK connects terrestrial and coastal practices within an integrated environmental system.

3 Result

3.1 Agroecological Knowledge: Forms and Ecological Functions

The results show that Agroecological Knowledge among the Madurese is expressed through seasonal farming calendars, crop rotation, and the interpretation of natural signs. These practices have developed through farmers' continuous observation of local environmental conditions. Rather than relying only on fixed agricultural schedules, farmers adjust their activities according to seasonal patterns and ecological indicators. The *nambhere'-nemor* calendar provides a local reference for determining appropriate periods for agricultural activities, while crop rotation and environmental observations support day-to-day farming decisions.

A comparative examination of these practices shows that each form of knowledge serves a distinct but interconnected ecological function. The *nambhere'-nemor* calendar supports adaptation to seasonal and climatic variation. The rotation of corn, beans, and tobacco helps maintain soil productivity through the alternation of crops across planting periods. Meanwhile, observations of wind, stars, and animal behavior provide environmental signals that help farmers anticipate changes in weather and seasonal conditions. These findings indicate that Madurese agroecological knowledge functions as an adaptive system for maintaining agricultural productivity and reducing environmental risks.

Table 1. Thematic Coding Summary of Agroecological Knowledge

Theme	Subtheme	Empirical Evidence	Ecological Function
Agroecological Knowledge	*nambhere'-nemor* planting calendar	Farmers identify planting periods according to seasonal patterns	Climate adaptation and reduction of crop-failure risks

Corn–bean–tobacco crop rotation	Farmers alternate crops across planting seasons	Maintenance of soil fertility and agricultural productivity
Interpretation of natural signs	Farmers observe wind, stars, and animal behavior	Anticipation of weather and seasonal changes
Integrated ecological observation	Agricultural decisions combine seasonal knowledge with environmental signs	Adaptive and sustainable farming practices

The thematic coding presented in Table 1 demonstrates that agroecological knowledge among the Madurese is organized around interconnected practices that support environmental adaptation and agricultural sustainability. The *nambhere'-nemor* planting calendar functions as a temporal guide that helps farmers align agricultural activities with seasonal conditions and reduce the risk of crop failure. Crop rotation practices involving corn, beans, and tobacco contribute to maintaining soil fertility and sustaining agricultural productivity across planting cycles. In addition, farmers continuously interpret natural signs, including wind direction, star positions, and animal behavior, to anticipate weather variability and seasonal transitions. These forms of knowledge are not applied independently; rather, they are integrated into a broader system of ecological observation that informs agricultural decision-making. Collectively, the findings indicate that Madurese agroecological knowledge represents an adaptive knowledge system through which farmers respond to environmental uncertainty while maintaining the long-term sustainability of agricultural production.

3.2 Coastal Ecological Knowledge: Forms and Ecological Functions

The findings show that Coastal Ecological Knowledge among the Madurese is reflected in knowledge of ocean currents, fishing seasons, customary fishing restrictions, and the *rokat tasè'* ritual. Fishers use knowledge of ocean conditions and seasonal patterns when determining fishing activities. They also observe customary restrictions on certain days when going to sea is avoided. These practices are accompanied by *rokat tasè'*, which expresses the community's relationship with the sea. The findings indicate that coastal knowledge is closely related to how fishing activities are organized and how marine resources are used.

Knowledge of ocean currents and fishing seasons is used in everyday fishing activities. Fishers identify marine conditions and seasonal periods before deciding when to go to sea. This knowledge helps them adjust fishing activities to changes in the marine environment. The practice shows that local knowledge of marine conditions has a direct role in fishing decisions.

The practice of avoiding the sea on certain days also forms part of local coastal knowledge. These restrictions establish periods when fishing activities are not carried out. The practice creates a break in fishing activities and reduces the intensity of resource use. Customary restrictions therefore have a practical function in limiting fishing pressure.

The *rokat tasè'* ritual represents the cultural dimension of this knowledge. The ritual is associated with the sea harvest and expresses respect for the sea and its resources. Unlike knowledge of currents and fishing seasons, its function is primarily cultural. However, it reinforces the community's recognition of the sea as an important part of their livelihood and social life. The ritual therefore provides a cultural basis for maintaining a respectful relationship with marine resources.

Overall, the findings show that Coastal Ecological Knowledge combines practical knowledge and customary practices. Knowledge of currents and fishing seasons guides fishing activities, while restrictions on certain days reduce fishing intensity. The *rokat tasè'* ritual reinforces the cultural meaning of the sea. These practices contribute to the regulation of marine-resource use and the maintenance of coastal-resource sustainability.

Table 2. Coastal Ecological Knowledge: Forms and Ecological Functions

Theme	Subtheme	Empirical Evidence	Ecological Function
Coastal Ecological Knowledge	Ocean-current knowledge	Fishers recognize ocean-current patterns when deciding where and when to fish.	Supporting fishing decisions
Coastal Ecological Knowledge	Fishing-season knowledge	Fishers recognize periods when fishing is more suitable based on seasonal patterns.	Adjusting fishing activities to seasonal cycles
Coastal Ecological Knowledge	Fishing-day restrictions	Fishers avoid going to sea on certain days according to local customary practice.	Reducing fishing pressure
Coastal Ecological Knowledge	*Rokat tasè'*	The community conducts *rokat tasè'* as part of its sea-harvest tradition.	Reinforcing respect for the sea and marine resources

The thematic coding presented in Table 2 illustrates that Coastal Ecological Knowledge among the Madurese encompasses both practical and cultural dimensions that contribute to the sustainable use of marine resources. Knowledge of ocean currents and fishing seasons provides fishers with ecological information that guides decisions regarding when and where fishing activities should be conducted. At the same time, customary restrictions on fishing days establish periodic limitations on resource extraction, thereby reducing fishing pressure and allowing marine ecosystems periods of recovery. The *rokat tasè'* ritual complements these practical practices by reinforcing cultural values of respect, gratitude, and responsibility toward the sea. Although its primary function is symbolic and cultural, the ritual strengthens community awareness of the importance of maintaining harmonious relationships with marine resources. Collectively, these findings suggest that Madurese coastal ecological knowledge operates as an integrated system in which environmental understanding, customary regulation, and cultural traditions interact to support the sustainability of coastal livelihoods and marine ecosystems.

3.3 Land–Sea Integration in Madurese Traditional Ecological Knowledge

The findings show that Madurese Traditional Ecological Knowledge connects agricultural and coastal practices through adaptation to environmental cycles and regulation of resource use. Agroecological Knowledge guides planting periods, crop rotation, and the interpretation of natural signs. Coastal Ecological Knowledge guides fishing activities through knowledge of ocean currents, fishing seasons, and customary restrictions. These practices occur in different environments but share a reliance on local observation and seasonal conditions. This connection shows that Madurese ecological knowledge can be understood across land and sea rather than as separate environmental practices.

The connection is particularly visible in the way environmental cycles influence both agricultural and fishing activities. Farmers use *nambhere'-nemor* and natural signs to determine agricultural activities. Fishers use ocean currents and fishing seasons to determine fishing activities. Both forms of knowledge are developed from repeated observation of environmental changes. Seasonal and ecological knowledge therefore provides a common basis for managing activities across terrestrial and coastal environments.

The two domains also differ in their forms of resource regulation. Agroecological Knowledge focuses on maintaining agricultural productivity through crop rotation and appropriate planting periods, while Coastal Ecological Knowledge includes restrictions that reduce fishing activities. The first regulates the use of cultivated land, while the second regulates access to marine resources. These differences reflect the specific conditions of each environment. Together, they show different forms of local regulation within the broader Madurese relationship with nature.

Table 3. Land–Sea Integration in Madurese Traditional Ecological Knowledge

Aspect	Agroecological Knowledge	Coastal Ecological Knowledge	Shared Ecological Principle
Environmental Sign	*Nambhere'-nemor* determines agricultural periods	Fishing seasons determine fishing periods	Adjusting activities to seasonal cycles
	Wind, stars, and animal behavior	Ocean currents and marine conditions	Using environmental signs to guide decisions
Resource management	Crop rotation manages agricultural land	Fishing restrictions reduce fishing pressure	Regulating resource use
	Seasonal knowledge reduces crop-failure risks	Fishing knowledge reduces inappropriate fishing activities	Adapting livelihoods to environmental variability

The findings presented in Table 3 demonstrate that Madurese Traditional Ecological Knowledge is organized around a common ecological logic that connects agricultural and coastal livelihoods. Although farming and fishing take place in different environmental settings, both rely on systematic observation of environmental conditions, seasonal rhythms, and ecological indicators to guide resource-use decisions. The comparison reveals that farmers employ the *nambhere'-nemor* calendar, wind patterns, stars, and animal behavior to determine planting schedules and agricultural activities, while

fishers utilize knowledge of ocean currents, marine conditions, and fishing seasons to organize fishing practices. These findings suggest that environmental observation serves as a shared knowledge base that enables communities to adapt their livelihoods to changing ecological conditions.

Table 3 further highlights the role of TEK in regulating resource use across both terrestrial and marine ecosystems. In agricultural contexts, crop rotation functions as a strategy for maintaining soil fertility and sustaining long-term productivity. In coastal contexts, customary restrictions on fishing days regulate access to marine resources and reduce fishing pressure during specific periods. Although these practices differ in form, both operate as locally developed mechanisms for balancing resource utilization with environmental sustainability. This indicates that resource management within Madurese communities is not solely based on economic considerations but is also shaped by ecological knowledge accumulated through generations of interaction with the environment.

Another important finding is the adaptive function of seasonal knowledge in reducing environmental risks. The *nambhere'-nemor* system helps farmers anticipate seasonal variability and minimize the risk of crop failure, whereas knowledge of fishing seasons and marine conditions assists fishers in avoiding unfavorable fishing periods. The shared emphasis on anticipating environmental change demonstrates that Madurese TEK functions as an adaptive system that supports livelihood resilience under uncertain ecological conditions. Collectively, the findings suggest that land-based and sea-based ecological practices should not be viewed as separate knowledge systems but rather as interconnected components of a broader ecological worldview that guides sustainable interactions between people and nature.

4 Discussion

The findings show that Madurese Traditional Ecological Knowledge connects agricultural and coastal practices through environmental observation and seasonal adjustment. This finding is consistent with [21], who found that Madurese farmers developed local knowledge through global sustainability principles with local ethical systems. Similar evidence is found in coastal Madurese communities where knowledge of marine conditions is embedded in everyday fishing practices [22]. The present study extends these findings by examining the two knowledge domains together. Agroecological and Coastal Ecological Knowledge therefore represent different expressions of local knowledge developed through interaction with distinct environments.

The role of environmental cycles provides a clear connection between the two domains. Farmers use *nambhere'-nemor* and natural signs such as wind, stars, and animal behavior to determine agricultural activities. Fishers use fishing seasons and ocean currents to determine when fishing activities should be undertaken. A similar relationship between ecological indicators and livelihood adaptation has been reported among Madurese coastal communities in Sumenep, where ecological indicators are used to respond to changes in seasonal conditions [10]. This finding is also consistent with [23], who showed that traditional agroecological knowledge can support adaptive resource

management through knowledge of changing environmental conditions. In the Madurese context, environmental observation provides a common basis for adjusting activities on both land and sea.

The findings also demonstrate that resource regulation takes different forms according to the ecological setting. Agroecological Knowledge regulates the use of cultivated land through crop rotation and appropriate planting periods. Coastal Ecological Knowledge regulates marine-resource use through fishing seasons and customary restrictions on going to sea. [24] similarly showed that Madurese agricultural knowledge is related to the management of natural resources in the traditional settlements. In coastal settings, the previous study on Gili Ketapang identified no-fishing practices and other customary practices as mechanisms that reduce fishing pressure [12]. The difference between the two domains lies in the resources being managed, while both involve locally established rules for adjusting resource use.

The findings are also relevant to the ICZM perspective because they demonstrate a relationship between terrestrial and coastal knowledge without suggesting that the community formally applies ICZM. Previous research has examined Madurese environmental knowledge in agricultural settings and marine settings. These studies provide evidence that local knowledge operates across different ecological environments [25]. The present study brings these findings together by identifying common elements in seasonal observation, environmental interpretation, and resource regulation. ICZM is therefore useful as an analytical lens for understanding how these two domains can be considered within a connected land–sea framework.

Overall, the findings extend previous studies by moving from separate descriptions of agricultural and coastal knowledge toward their relationship within Madurese environmental practices. Agroecological Knowledge focuses on agricultural land, while Coastal Ecological Knowledge focuses on marine resources. Both are shaped by environmental observation and adjustment to ecological cycles. This connection provides a more specific understanding of Madurese TEK as knowledge that operates across different environments. The contribution of this study lies in identifying the shared ecological principles that connect land-based and coastal practices within the Madurese context.

This study has both theoretical and practical implications while acknowledging several limitations. Theoretically, it extends the study of TEK by connecting Agroecological Knowledge and Coastal Ecological Knowledge through an ICZM lens. This perspective moves beyond treating agricultural and coastal knowledge as separate domains and highlights their shared basis in environmental observation, seasonal adaptation, and resource regulation. Practically, the findings highlight the importance of documenting and maintaining Madurese ecological knowledge as part of local environmental management and cultural continuity. However, the study is limited by its qualitative scope and the specific cultural and ecological context of the Madurese community examined. The findings therefore cannot be generalized to all Madurese communities or other coastal societies without further investigation. Future research should examine the land–sea relationship across different Madurese regions and combine ethnographic findings with ecological data to assess the environmental effects of specific traditional practices.

5 Conclusion

This study demonstrates that Madurese Traditional Ecological Knowledge operates across agricultural and coastal environments through locally developed practices of environmental observation, seasonal adaptation, and resource regulation. Agroecological Knowledge is expressed through the *nambhere'-nemor* planting calendar, corn–bean–tobacco crop rotation, and interpretation of wind, stars, and animal behavior. Coastal Ecological Knowledge is expressed through knowledge of ocean currents and fishing seasons, customary restrictions on going to sea, and the *rokat tasè'* ritual. Together, these findings show that Madurese ecological knowledge connects livelihood practices with environmental cycles and resource conditions across land and sea.

Theoretically, this study contributes to the discussion of Traditional Ecological Knowledge by applying an Integrated Coastal Zone Management (ICZM) lens to the relationship between agricultural and coastal knowledge. ICZM is used here as an analytical lens rather than as a formal management system practiced by the community. The findings suggest that the two knowledge domains have different practices but share principles of environmental observation, seasonal adjustment, and resource regulation. Further research should examine how this land–sea relationship operates in other Madurese communities and how specific traditional practices relate to measurable environmental outcomes.

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