Mata Tahun: Bridging indigenous knowledge and policy for ecosystem sustainability in the Mului Community, East Kalimantan amidst climate change

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Abstract. The traditional celestial calendar, known as Mata Tahun, is an indigenous knowledge system utilized by the forest-based Mului community in East Kalimantan. This system functions not only as a guide for agricultural timing but also as a mechanism for sustaining ecosystem balance and reinforcing cultural resilience. By observing star movements and weather patterns, the Mului community harmonizes their activities with natural cycles, preserving knowledge passed down through generations. However, climate change disrupts these celestial patterns, making it increasingly difficult to determine planting and harvesting periods accurately. Simultaneously, modernization and state-driven forest management policies often overlook the value of indigenous ecological knowledge, threatening the sustainability of customary forests. This study highlights the critical need for policy transformation that integrates Mata Tahun into state environmental management strategies. The research highlights how recognizing indigenous knowledge as a legitimate component of environmental governance can enhance climate adaptation strategies and strengthen ecosystem resilience. Incorporating local knowledge systems, such as Mata Tahun, into state forest management policies not only sustains the biodiversity of customary forests but also empowers indigenous communities to lead in climate change mitigation efforts. Bridging indigenous knowledge with formal governance can enhance ecological sustainability, support climate adaptation, and fortify the cultural identity of indigenous communities facing the pressures of environmental and social change.

1 Introduction

Traditional ecological knowledge, often called the Indigenous Knowledge System, consistently highlights the crucial role of indigenous communities in managing ecosystems

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and preserving the environment. Knowledge passed down through generations within these communities significantly contributes to maintaining ecological balance and promoting sustainable resource management [2, 5]. Indigenous knowledge systems represent a comprehensive understanding of local ecosystems and embody a holistic approach that integrates environmental management with the socio-cultural and spiritual dimensions of Indigenous life.

Traditional knowledge strengthens ecosystem resilience and cultural sustainability in the face of global challenges such as climate change and deforestation. This knowledge can contribute to adaptive management that supports ecosystem sustainability [2]. Indigenous knowledge is critical in addressing environmental challenges and promoting cultural sustainability [11]. When integrated with scientific approaches, traditional ecological knowledge enhances governance and ecosystem sustainability, enabling more effective management practices that respect indigenous wisdom and strengthen resilience in changing environments [13].

The Mului community, an indigenous group living in Penajam Paser Utara, East Kalimantan, demonstrates a profound commitment to environmental stewardship. Recognized as an Indigenous Peoples Community (MHA) in 2020, the Mului people manage 7,806 hectares of customary forest [6]. This formal recognition reflects their pivotal role in protecting forest ecosystems while preserving traditional practices. Their dedication to sustainable forest management was further honored in 2022 when they received the prestigious Kalpataru Award for environmental change mitigation efforts, recognizing their ongoing care and commitment to Indonesia's environment [12]. This award highlights the community's outstanding conservation efforts and the preservation of traditional ecological knowledge. It becomes increasingly vital as they face modern challenges like climate change affecting forest-dwelling communities.

For the Mului people, the forest is more than just a physical space — it is the foundation of their cultural identity and livelihood. Their deep reliance on forest resources provides food and materials for daily life and serves as a repository of medicinal plants, spiritual significance, and ecological balance. Their guiding philosophy, Jatas Tete, encapsulates this profound connection, which translates to "The forest is mother's milk" [6]. This phrase reflects the community's view of the forest as a nurturing entity that sustains life, much like a mother caring for her child. For the Mului people, sustainable forest management is not merely about resource use but represents the foundation of their existence, cultural continuity, and spiritual well-being.

The Mului community's forest resource management practices are guided by a sense of responsibility and respect through the Mata Tahun calendar mechanism, which ensures their practices remain aligned and sustainable for future generations. Beyond being a traditional celestial calendar for preserving indigenous knowledge and forest ecosystems, Mata Tahun is a tangible manifestation of adaptation and mitigation in response to climate change. Historically, local knowledge has shaped ecological approaches that have been studied and passed down to navigate unpredictable environmental conditions. The practice of Mata Tahun illustrates the community's comprehensive understanding of their sensitivity to forest ecosystems, even as they face increasingly complex environmental challenges.

2 Method

This research employs a qualitative approach with ethnographic methods to deeply understand the practice of using the Mata Tahun calendar within the Mului indigenous community. Data were collected through in-depth interviews with traditional elders, farmers, and forest guardians to explore how they interpret natural signs and regulate seasonal activities. Focus group discussions (FGD) were conducted to enrich collective perspectives

on adaptation strategies to environmental changes and the challenges they face. Additionally, participant observation allowed researchers to directly experience the rituals and agricultural practices based on the traditional calendar, strengthening the understanding of the community's dynamic interactions with the forest ecosystem.

To complement the primary data, this study also analyzed secondary data through local policy documents, historical records, and previous studies on forest management in the Mului community. Thematic analysis was applied to identify patterns, meanings, and values embedded in community narratives, which were then interpreted within the framework of cultural ecology theory and sustainable resource governance. This approach enables a holistic understanding of how local knowledge, such as Mata Tahun, can be vital for strengthening community resilience and promoting integration with state-level environmental management policies.

3 Result and Discussion

3.1 The Mului Community's Mata Tahun calendar in preserving indigenous knowledge and forest ecosystems

The Mata Tahun system, a key aspect of ethnoastronomy in the Mului community, relies on natural signs and celestial bodies to regulate seasonal activities. Integrating celestial events into agricultural practices highlights the importance of traditional ecological knowledge in sustainable resource management [4]. For example, the start of the dry season is marked by Wayat (strong winds), while the appearance of three chirping birds signals the arrival of visitors. The community's seasonal calculations revolve around stars and the moon, with specific stars carrying distinct meanings. For instance, Bintang Turu' (Seven Stars) signals the start of the dry season, typically in the fourth month of the Mului calendar, indicating the time to clear and dry new fields. Bintang Tolu (Three Stars) marks a sufficiently hot season, ideal for drying fields during the fifth month of the Paser calendar. Bintang Mamanuk indicates hot days in the sixth month, making it an optimal time to burn fields and turn wood into ash. Notably, the seventh month lacks a specific star sign and is traditionally recognized as planting time.

The Mului calendar follows a 30-day cycle, with the first month aligning with May in the national calendar. Agricultural activities, such as land clearing, are heavily dependent on the clarity of starlight. If the stars are absent during the designated month, these activities may be postponed and rescheduled for another month, such as the seventh or ninth month. This practice demonstrates the community's strong emphasis on harmony with nature, ensuring that their agricultural practices remain aligned with natural cycles and celestial signs. The following table illustrates the annual cycle of activities based on the traditional calendar, showing how different months align with specific agricultural and forestry practices.

Through the Mata Tahun calendar mechanism, the Mului community practices land management that reflects a profound respect for nature. The rules established through their relationship with the environment create wise principles for land management. Their land is divided into several distinct zones based on function, ensuring the efficient use of natural resources [11]. Umo (fields) are designated agricultural areas where rice, corn, vegetables, and other crops are cultivated to sustain the community's food supply. Surrounding these fields are Lati (shrubs), further classified into Lati Tuo (old shrubs) and Lati Burok (young shrubs), as illustrated in the land management map below.

Table 1. The Mului calendar (Lembaga Adat Mului, 2020)

Month	Activity	Location
May - June	Sacred Rituals and Gathering of Forest Produce	Settlement/Forest
July	Land Clearing	Umo
August	Planting and Preparation	Umo
September – October	Tending to Crops, Protecting from Pests	Umo
November	Waiting for the Harvest (*Jagong*)	Umo
December – January	Harvesting Crops	Umo
February – March	Post-Harvest Activities, Returning to Forest Resources	Umo/Forest
April	Rest and Preparation for New Season	Settlement

The map above illustrates sustainable forest management by the Mului community, with designated zones for agriculture, hunting, and sacred conservation areas. The Mata Tahun calendar is used in communal agricultural zones, which are reserved as backup fields for future planting and serve as crucial habitats for hunting. Beyond the shrublands lie the Alas (forest), further divided into Alas Tuo (old forest) and Alas Burok (young forest). The forest is vital for providing natural resources, such as timber, and also serves as the primary hunting ground. Near the settlement, there are mixed gardens where various plants like fruits, sugar palms, betel nuts, and coffee are grown, contributing to the community's livelihood and daily needs. This careful division of forest zones enables the Mului community to maintain a harmonious balance between resource extraction and ecosystem preservation, ensuring long-term sustainability for both their environment and cultural heritage.

3.1.1 Mata Tahun and ecosystem sustainability

The Mata Tahun calendar plays a vital role in guiding the agricultural practices of the Mului community by aligning them with natural cycles. Using this traditional calendar, the community can determine the optimal timing for planting and harvesting, supporting sustainable land use and preventing overexploitation of resources. This careful synchronization meets immediate agricultural needs and ensures long-term land productivity, contributing to overall ecosystem health. Traditional practices, such as using the indigenous calendar, significantly contribute to sustainable resource management by fostering a symbiotic relationship between the community and their environment [2].

The Mata Tahun system holds deep significance for the Multi Indigenous community, particularly in their knowledge of adapting to various weather conditions. It serves as a primary tool for determining the ideal times for planting and harvesting based on local weather patterns and for employing precise agricultural techniques believed to minimize adverse impacts on their livelihoods.

In 2023, climate change impacted the ecosystem, disrupting the natural balance between the Indigenous community and their natural resources. This situation worsened the availability of forest products for the community, such as wild honey and fruits. At this stage, the Multi Indigenous community strives to survive by implementing flexible ecosystem management and adapting to environmental changes caused by natural shifts and human activities outside their territory. Sustainable natural resource management is essential to reduce the impacts of climate change. An ecosystem-based approach incorporates often overlooked physical environmental factors, encouraging people to strengthen cultural and ecological approaches by emphasizing reciprocal causal relationships [8]. Indigenous communities continuously strive for sustainable forest management and biodiversity conservation. The cultural ecology approach is applied to maintain ecosystem balance and

enhance resilience to change. Climate change motivates them to adjust their forest management in response to shifting conditions. This ecosystem management effort includes restoring degraded ecosystems caused by external factors. This process involves restoring ecosystem functions and structures through their belief system to recover lost natural resources and biodiversity.

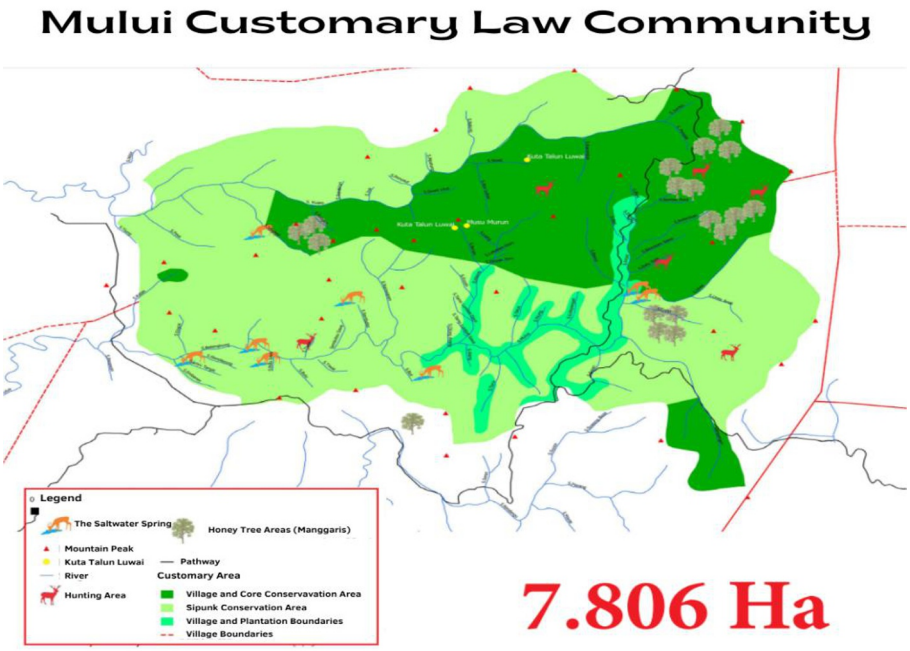

Fig. 1. Land management map of the Mului People's customary forest (Lembaga Adat Mului, 2020)

In facing climate change, traditional knowledge embedded in the Mata Tahun calendar offers valuable insights into adaptive strategies that modern agricultural systems may overlook. For instance, the Mului community can adjust their agricultural cycles in response to changing weather patterns or the emergence of pests, thereby increasing their resilience to climate-related challenges. This flexibility is crucial as global climate patterns become increasingly unpredictable. Studies show that indigenous communities hold extensive knowledge about local environmental changes and adaptive practices that can inform broader climate adaptation strategies [3]. By combining traditional ecological knowledge with contemporary approaches, the Mului community can navigate the complexities of climate change while preserving their cultural heritage.

Local knowledge of sustainable resource management has helped the Mului community maintain ecological balance and prevent forest degradation through traditional practices and rituals. The Mului community's understanding of human-environment relationships is highly complex, grounded in cultural knowledge that sustains ongoing interactions and how cultural studies deepen insights into human ecology and foster more profound discussions about sustainable living [7]. As a form of local wisdom, the Mata Tahun system integrates sustainable natural resource management practices that help indigenous communities maintain ecological balance and prevent degradation caused by human interference. The community has developed a sustainable relationship between humans and nature through extensive environmental observation, particularly in detecting shifts in forest product patterns and wildlife availability. In this context, local knowledge becomes essential in assessing the consequences of human actions on the environment.

The Mata Tahun system represents the cultural diversity of the Multi Indigenous community in observing and applying knowledge to their surrounding environment. The Mata Tahun calendar exemplifies cultural achievements in creating local knowledge that fosters ecological wisdom, demonstrating how humans interact with nature to maximize survival opportunities. Through local knowledge, indigenous communities can offer some of the best approaches for conserving and protecting biodiversity. Based on holistic studies of human interactions with the physical environment, this relationship has formed through structure, function, and balance, demonstrating general principles in biology and anthropology [7]. The human-nature relationship is depicted in the structure of Mata Tahun, which requires the creation of complex ecosystem management components that interact with other systems, including biotic elements (such as flora and fauna) and abiotic elements (such as soil and water). This reciprocal relationship enables indigenous communities to understand how interconnected ecosystems influence one another. The community's sensitivity has evolved in reading about natural resources and wildlife changes in this context. Naturally, local knowledge builds ecological resilience within the established ecosystem boundaries, primarily through understanding how ecosystems function optimally and how communities can adapt to change.

3.1.2 Integrating traditional knowledge with state policies

The primary step toward integrating traditional knowledge with state policies is formally recognizing indigenous knowledge systems like Mata Tahun. The government can acknowledge the importance of this system in shaping environmental and agricultural policies, ensuring that traditional practices are respected and incorporated into formal governance frameworks. Such recognition validates the cultural significance of indigenous knowledge and empowers local communities to participate in decision-making processes. According to the United Nations Declaration on the Rights of Indigenous Peoples, respecting traditional knowledge is essential for promoting sustainable development and biodiversity conservation [14]. By recognizing Mata Tahun, the government can enhance the effectiveness of policies aimed at environmental management, setting a precedent for further integrating traditional practices into policy frameworks.

Building on the recognition of indigenous knowledge, incorporating the Mata Tahun star calendar into local and national forest and land management strategies can contribute significantly to sustainable resource management. The calendar's deep connection to natural cycles allows the Mului community to time their agricultural practices in harmony with ecological rhythms, ensuring the sustainable use of resources. This traditional knowledge can enhance ecosystem conservation and resilience when integrated into formal land management frameworks. Research shows that combining indigenous practices with scientific approaches leads to better resource management outcomes, as it leverages the strengths of both systems [2]. This synergy fosters sustainable development and reinforces the foundation established by recognizing indigenous knowledge in governance.

Integrating the Mata Tahun system into climate adaptation policies can enhance cultural relevance and effectiveness. By acknowledging traditional knowledge, policymakers can develop initiatives that align with local communities, enabling a more community-based approach to climate change adaptation. The alignment between traditional practices and modern environmental goals facilitates a more inclusive and holistic approach to addressing climate challenges. Research has shown that integrating local knowledge into climate policies can result in more effective and resilient adaptation strategies [10]. Thus, recognizing indigenous systems serves as a crucial stepping stone for crafting policies that are scientifically sound, culturally appropriate, and widely accepted.

Beyond climate adaptation, blending the traditional knowledge of the Mata Tahun system with modern technology presents opportunities to develop hybrid environmental monitoring systems. By integrating seasonal predictions derived from the Mata Tahun calendar with contemporary tools like satellite data, communities can enhance the accuracy of agriculture, forestry, and resource management. This collaborative approach improves environmental monitoring precision and validates traditional knowledge through modern scientific methods. Studies indicate that such hybrid systems can facilitate adaptive management practices, making them more responsive to changing environmental conditions [9]. Therefore, integrating traditional knowledge into monitoring systems underscores the importance of indigenous practices in modern resource management.

Finally, promoting education and training programs that incorporate the Mata Tahun calendar into local curricula is essential for fostering awareness and resilience in the face of climate change. By teaching this traditional knowledge alongside modern environmental science, policymakers can cultivate a generation that values indigenous practices while being equipped with contemporary scientific knowledge. This fusion of knowledge systems enhances environmental literacy and strengthens community bonds with their cultural heritage. Research has shown that education that respects and integrates traditional knowledge fosters greater community engagement and resilience [1]. As a result, these programs can play a vital role in preparing communities to effectively respond to environmental challenges, ensuring that the recognition of indigenous knowledge translates into meaningful actions and sustainable practices.

4 Conclusion

The Mata Tahun celestial calendar embodies a deeply rooted indigenous knowledge system within the Mului community, serving as a vital tool for sustainable ecosystem management in East Kalimantan. By blending astronomical observations with their agricultural practices, the Mului people maintain a harmonious relationship with their environment. This traditional knowledge ensures optimal timing for agricultural activities and fosters cultural resilience and environmental stewardship. As climate change increasingly disrupts natural cycles, preserving this indigenous knowledge becomes crucial for maintaining ecological balance and safeguarding the cultural identity of the Mului community.

In conclusion, the Mata Tahun system exemplifies how indigenous knowledge can inform and enrich modern approaches to sustainable development. As global environmental challenges intensify, incorporating the perspectives and practices of indigenous communities into policy frameworks will be essential for promoting resilience and sustainability. By valuing and respecting the insights offered by communities like the Mului, society can work toward a more just and ecologically conscious future, ensuring that cultural heritage and ecosystem health are preserved for future generations.

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