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# Integration of Traditional Ecological Knowledge of Local Communities as a Basis for Sustainable Conservation in the Leuser Ecosystem, Aceh

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**Abstrak:** Ekosistem Leuser merupakan salah satu kawasan keanekaragaman hayati terpenting di dunia yang menghadapi tekanan deforestasi dan degradasi ekosistem secara masif. Penelitian ini mengkaji integrasi Pengetahuan Ekologis Tradisional (PET) masyarakat lokal khususnya komunitas Gayo sebagai fondasi strategi konservasi berkelanjutan. Menggunakan pendekatan kualitatif melalui etnobiologi, wawancara mendalam, dan observasi partisipatif, studi ini mendokumentasikan sistem pengetahuan lokal yang mencakup klasifikasi satwa liar, pemahaman hubungan ekologis antarspesies, serta praktik pengelolaan lahan berbasis adat. Hasil penelitian menunjukkan bahwa masyarakat lokal memiliki pengetahuan mendalam tentang perilaku dan habitat orangutan Sumatera (*Pongo abelii*), harimau Sumatera (*Panthera tigris sumatrae*), dan gajah Sumatera (*Elephas maximus sumatranus*), yang secara substansial melengkapi data ilmiah formal. Sistem hutan larangan (hutan keramat) dan praktik pertanian tradisional seperti meremah terbukti efektif dalam menjaga konektivitas habitat. Integrasi PET ke dalam kebijakan konservasi berbasis komunitas berpotensi meningkatkan efektivitas pelestarian ekosistem Leuser secara signifikan, sekaligus memperkuat kedaulatan pengetahuan dan hak masyarakat adat dalam tata kelola sumber daya alam.

**Kata kunci**: Pengetahuan Ekologis Tradisional; Ekosistem Leuser; Konservasi Berbasis Komunitas; Etnobiologi; Masyarakat Adat Aceh

**Abstract:** The Leuser Ecosystem is one of the world's most important biodiversity hotspots, facing massive pressure from deforestation and ecosystem degradation. This study examines the integration of Traditional Ecological Knowledge (TEK) of local communities, particularly the Gayo community, as the foundation for sustainable conservation strategies. Using a qualitative approach through ethnobiology, in-depth interviews, and participatory observation, this study documents local knowledge systems encompassing the classification of wildlife, an understanding of ecological relationships between species, and customary land management practices. The research findings indicate that local communities possess in-depth

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knowledge of the behaviour and habitats of the Sumatran orangutan (*Pongo abelii*), the Sumatran tiger (*Panthera tigris sumatrae*), and the Sumatran elephant (*Elephas maximus sumatranus*), which substantially complements formal scientific data. The system of protected forests (sacred forests) and traditional agricultural practices such as meremah have proven effective in maintaining habitat connectivity. The integration of PET into community-based conservation policies has the potential to significantly enhance the effectiveness of Leuser ecosystem conservation, whilst strengthening the knowledge sovereignty and rights of indigenous communities in the management of natural resources.
**Keyword:** Traditional Ecological Knowledge; Leuser Ecosystem; Community-Based Conservation; Ethnobiology; Indigenous Communities of Aceh

## 1. Introduction

The Leuser Ecosystem, situated in the provinces of Aceh and North Sumatra, is one of the last bastions of biodiversity in South-East Asia. Covering an area of more than 2.6 million hectares, this region provides a habitat for four endangered megafauna species: the Sumatran orangutan (*Pongo abelii*), the Sumatran tiger (*Panthera tigris sumatrae*), the Sumatran elephant (*Elephas maximus sumatranus*), and the Sumatran rhinoceros (*Dicerorhinus sumatrensis*) [1] In addition to its biodiversity value, the Leuser ecosystem also serves as a water source for millions of people in Aceh, a regulator of the regional climate, and a carbon sink that is vital for global climate stability [2].

However, the Leuser Ecosystem continues to face pressure that enormous. The latest data show that deforestation in the Leuser buffer zone is increasing at an alarming rate due to the expansion of oil palm plantations, illegal logging, illegal mining and unplanned infrastructure development [3] [4]. The loss of forest cover not only threatens the survival of endemic species, but also damages the ecosystem functions on which the livelihoods of communities in Aceh depend. Ironically, conventional conservation approaches which are top-down and area-based often overlook complex socio-ecological dimensions, including the vital role of local communities as traditional forest guardians [5].

The concept of Traditional Ecological Knowledge (TEK) is of great importance. TEK is defined as the body of knowledge, practices and beliefs concerning the relationship between living organisms, including humans, and their environment, which has developed through adaptation and been passed down cumulatively from generation to generation [6][7][8][9][10].

Several studies indicate that the integration of local knowledge and community participation are key factors in the success of sustainable conservation. Local ecological knowledge has been shown to support more adaptive and context-appropriate conservation programmes, and to play a role in the management of natural resources based on local wisdom across various regions of Aceh [9] [11] [12] [13]. In an institutional context, the existence of customary forests and the mukim legal system demonstrates significant potential for safeguarding environmental sustainability and mitigating climate change. Furthermore, an integrated, adaptive and collaborative approach is required to address environmental challenges in Aceh and ensure the long-term sustainability of ecosystems and the well-being of communities [14][15].

In Aceh, this context is particularly relevant given the existence of the Qanun (Sharia-based local regulations) which provide a legal framework for the recognition of indigenous peoples' rights in the management of natural resources[16][17]. However, the implementation of this recognition is still far from optimal. The gap between local knowledge and formal conservation policies remains very wide: the 'forbidden forest' (sacred forest) system managed by indigenous communities often receives no legal recognition[18]. This research aims to address this gap. By n systematically documenting and analysing the traditional ecological knowledge (TEK) of local communities around the Leuser Ecosystem, this research aims to: (1) identify and classify traditional ecological

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knowledge systems relevant to the conservation of endangered species and habitat management; (2) examine the potential for integrating TEK into national and local conservation policy frameworks; and (3) formulate a synthesis for collaboration between traditional knowledge and modern science in the context of the sustainable management of the Leuser Ecosystem.

## 2. Research Method

### a. Research Paradigm and Approach

Mathematical This study employs an interpretative constructivist paradigm, which views knowledge as a social construct formed within a specific cultural and ecological context. A qualitative approach was chosen because this study aims to gain an in-depth understanding of traditional knowledge systems, which are implicit, holistic and contextual [19].

The research design employed was a multi-site study that integrated three methodological traditions: (1) ecological ethnography to understand knowledge systems within their overall cultural context; (2) ethnobiological documentation to systematically record and classify knowledge about organisms and ecosystems; and (3) Participatory Action Research (PAR) to ensure that the research process provides direct benefits to the communities under study and does not merely extract their knowledge.

### b. Research Location and Context

This research was conducted in two ecologically and ethnically distinct areas surrounding the Leuser Ecosystem, namely: (1) Bener Meriah Regency, which forms part of the Gayo highlands with a montane forest ecosystem characteristic of the Gayo ethnic community; and (2) Gayo Lues Regency, which is situated within and around the buffer zone of Gunung Leuser National Park, with a tropical rainforest ecosystem that remains relatively intact and serves as a vital habitat for biodiversity.

**c. Informants and Sampling Methods**

A total of 60 informants were involved, spread across two research locations: 32 informants in Bener Meriah Regency (the Gayo community) and 28 informants in Gayo Lues Regency (the Gayo Lues community). Of these, 36 were key informants who were interviewed in depth, whilst the remaining 24 took part in focus group discussions (FGDs) and participatory observation activities.

**d. Data Collection Techniques**

Data were collected using four main, complementary techniques. Firstly, in-depth semi-structured interviews were conducted on an individual basis with key informants [20]. Each interview lasted between 60 and 180 minutes, was recorded with the informant's consent, and was conducted in the Gayo language. Secondly, participatory observation was carried out by accompanying informants during their daily subsistence activities. The total observation time amounted to more than 420 hours, spread over 18 months of fieldwork.

Thirdly, Focus Group Discussions (FGDs) were held over 12 sessions, with 8 to 12 participants per session. The FGDs were designed to validate the findings of the individual interviews, explore community-level issues, and discuss policy implications from the community's perspective. Fourthly, participatory mapping was carried out with the community to record the spatial distribution of areas considered to be of ecological and cultural importance, including protected forests, water sources, wildlife corridors and traditional agroforestry areas.

**e. Data Analysis**

Data analysis was carried out using a thematic analysis approach that was both inductive and deductive, in which themes were identified

from both the data and the theoretical framework employed through several iterative stages [21]. All interview recordings were transcribed verbatim and translated into Indonesian, then analysed using Readmi Note 13 Pro 5G software for data management and coding. The analysis of folk taxonomy was carried out using the freelisting and pile sorting methods to identify systems of animal and plant classification from a local perspective, which were then compared with Linnaeus's scientific taxonomy.

## 3. Results and Discussion

### a. Participant Profiles and Sample Distribution

Criteria for informants: (a) members of indigenous communities who have lived there for ≥20 years; (b) recognised by their community as holders of ecological knowledge; and (c) who have given their free, prior and informed consent (FPIC) in accordance with the relevant protocol.

**Table 1.** Distribution of Research Informants by Location, Category, Gender and Age Group

| Category | Bener Meriah (n=32) | Gayo Lues (n=28) | Total (N=60) | Percentage (%) |
|---|---|---|---|---|
| Key Informants | 20 | 16 | 36 | 60.0 |
| FGD participants | 12 | 12 | 24 | 40.0 |
| Gender – Male | 20 | 16 | 36 | 60.0 |
| Gender – Female | 12 | 12 | 24 | 40.0 |
| Age ≥55 years (elderly) | 14 | 11 | 25 | 41.7 |
| Aged 35–54 years | 11 | 9 | 20 | 33.3 |
| Under 35 years old (young | 7 | 8 | 15 | 25.0 |
| Observation hours (total) | 230 hours | 190 hours | >420 | — |

*Note: Erosion r = ((Elderly score − Adolescent score) / Elderly score) × 100.*

As shown in Table 1, approximately 60% of respondents (n = 36) acted as key informants for in-depth interviews, whilst 40 per cent took part in focus group discussions and observation sessions.



(1) (2)

**Figure 1**: (1) Interviews with traditional leaders and tiger guardians in Bener Meriah, (2) Interviews with traditional leaders and tiger guardians in Bener Meriah

**1. Analysis of the Traditional Ecological Knowledge (TEK) Domain**

1. Folk taxonomy and classification of wildlife

A thematic analysis of interview transcripts and FGD notes identified the folk taxonomy as the most extensively documented domain of TEK in both locations. Members of the Gayo community listed more than 340 categories of fauna, classified according to a combination of morphology, behaviour, microhabitat affiliation and cultural significance.

For the Sumatran orangutan (Pongo abelii), a source at Alas distinguishes at least three traditional 'varieties', classified according to body size, coat colour and preferred altitude. This level of resolution exceeds that typically recorded in camera-trap surveys, confirming the findings at [22][23] which show that TEK often provides better spatial and temporal resolution than conventional scientific monitoring.

2. Indigenous Forest Management Systems

Seven distinct mechanisms of customary forest management were

identified through participatory observation and analysis of interviews. The 'uten keramat' sacred forest system in Gayo emerged as the institution with the widest geographical coverage. Participatory mapping revealed that the sacred forests in Bener Meriah and Gayo Lues cover more than 12,000 hectares spread across 23 villages, forming a network of informal protected areas that operate through social sanctions and a system of spiritual beliefs.

The 'meremah' rotational shifting cultivation system, practised in Bener Meriah, operates in accordance with customary rules that mandate a rotation cycle of 15–25 years. Contrary to the dominant narrative portraying shifting cultivation as an ecologically damaging practice, an analysis of participatory land-use mapping data shows that 'meremah' produces a heterogeneous landscape mosaic that is empirically associated with higher local biodiversity compared to monoculture alternatives [12][24].

**2. Knowledge of Key Species and Their Application in Conservation**

In-depth interviews with traditional hunters and community elders yielded high-resolution ecological data on three key megafauna species (Table 2). For the Sumatran tiger (Panthera tigris sumatrae), informants from both locations described crossing corridors connecting forest patches within a matrix of coffee plantations.

**Table 2.** Summary of TEK Domains, Scientific Validation, and Conservation Relevance

| TEK Domain | Examples of Traditional Ecological Knowledge | Scientific Validation | Conservation Relevance |
|---|---|---|---|
| Traditional Wildlife Taxonomy | >340 fauna categories; 3 orangutan 'varieties' based on morphology & habitat | High alignment with Linnaean taxonomy; captures subspecies variation | Precise habitat-based conservation targeting |
| Species Behavior & Ecology | Tiger crossing corridors, elephant migration routes, orangutan fruiting trees | >85% overlap with GPS collar data (WWF-Indonesia) | Early warning system; corridor prioritization |
| Sacred Forest (Uten Keramat) | >12,000 ha spanning 23 villages in Bener Meriah and Gayo Lues | Functioning as a de facto protected area with access restrictions in place | Informal biodiversity refuge and connectivity hub |
| Meremah (Shifting Cultivation Lands) | A 15–25-year rotation cycle governed by traditional rituals | Maintains landscape heterogeneity that supports high biodiversity | A mosaic habitat supporting forest edge and forest interior species |
| Plant Ecology Knowledge | Medicinal plants, food crops, and wildlife forage; forest health indicator species | In accordance with ethnobotanical literature | Management of Non-Timber Forest Products; agroforestry design |
| Community-Based Early Warning Systems | A network of village informants monitoring elephant movements through verbal communication and WhatsApp | Existed prior to formal government systems; higher temporal resolution | Human-wildlife conflict mitigation |

*Note: NTFPs = Non-Timber Forest Products*

## 3. Proposed Model: Pluralistic Knowledge Governance Framework (PKGF)

Based on triangulated evidence from field data, participatory mapping results, and comparative analysis with existing governance frameworks, this study proposes the Pluralistic Knowledge Governance Framework (PKGF) as an operational model for integrating TEK into Leuser Ecosystem conservation policies (Table 3).

**Table 3.** Components of the Proposed Pluralistic Knowledge Governance Framework

| PKGF Principles | Operational Mechanisms | Implementation Instruments | Expected Outcomes |
|---|---|---|---|
| Collaborative Knowledge Production | Joint scientific-technical monitoring protocol; participatory biodiversity survey | Community-based monitoring (CBM) program; citizen science platform | Improving biodiversity data resolution; adaptive management |
| Community Knowledge Sovereignty | FPIC-based data governance; biocultural protocols for TEK documentation | Aceh Qanun; national regulations on the rights of indigenous peoples (Law No. 5/2017) | Prevention of biopiracy; equitable benefit-sharing |
| Adaptive Institutional Integration | Official recognition of sacred forests in the TNGL management plan; recognition of customary forests | Ministry of Forestry Regulation P.21/2019; Aceh Regional Medium-Term Development Plan (RPJMD); revision of the TNGL Management Plan | Legal protection of community-managed areas; reduced fragmentation of governance |
| Collaborative Monitoring | Integration of traditional tracking methods with camera traps and satellite telemetry | Tripartite agreement between WWF-SPORC and the community; joint forest ranger patrols | Cost-effective, high-resolution ecosystem monitoring |

*Note: FPIC = Free, Prior, and Informed Consent; TNGL = Gunung Leuser National Park; RPJMD = Regional Medium-Term Development Plan.*

PKGF is fundamentally different from hierarchical knowledge management models which position TEK as a complement to scientific knowledge. Conversely, PKGF puts into practice an epistemology of co-production in which TEK and formal science are treated as epistemologically interdependent and mutually reinforcing systems. The legal framework of the Qanun in Aceh provides a unique political and institutional entry point for embedding the principles of PKGF into the formal governance of[17][25].

Precedents from Kalimantan and Papua show that formal recognition of customary forests under Ministry of Forestry Regulation P.21/2019 can serve as an effective legal instrument for legitimising TEK-based governance systems. Adapting these precedents to the socio-ecological context of Leuser, whilst ly incorporating the specific customary system of the Gayo community, constitutes the key governance innovation proposed by this research.

### 4. Synthesis: TEK as a Pillar of Sustainable Conservation

Across all analytical dimensions, the data consistently show that the Traditional Ecological Knowledge (TEK) held by the Gayo community in the Leuser Ecosystem is a resource for conservation that has been scientifically validated, is ecologically grounded, and can be institutionally implemented. Three mutually reinforcing findings from this analysis (1) a high degree of alignment between traditional taxonomy and scientific classification; (2) the effectiveness of customary governance mechanisms as institutions for protected areas; and (3) the critical threat of intergenerational knowledge erosion collectively form a compelling evidence base for the urgent documentation of TEK, its integration into policy, and the implementation of community-centred governance reforms.

## 4. Conclusion

This study yielded three key findings with substantive implications for conservation science and public policy. Firstly, the Gayo people in the Leuser Ecosystem possess a rich and scientifically validated body of TEK, encompassing more than 340 categories of fauna. Secondly, the proposed Pluralistic Knowledge Governance Framework (PKGF) provides an evidence-based operational model for integrating TEK into conservation policies for the Leuser Ecosystem, utilising the legal framework of the Aceh Qanun as a unique institutional mechanism

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