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Research paper

Integrating Gayo Ethnozoological Knowledge into Sustainable Buffalo Husbandry Policies in Aceh, Indonesia

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Abstract

This study examines how Gayo ethnozoological knowledge can inform sustainable buffalo husbandry policies in Aceh, Indonesia. The Gayo buffalo (Bubalus bubalis) serves as a vital local genetic and cultural resource amid growing challenges in livestock conservation and food security. Through ethnographic research, the study highlights how traditional ecological knowledge—particularly the Gayo people's ethnotaxonomic system—contributes to understanding and managing genetic diversity. The findings demonstrate that this indigenous classification system reflects deep cultural insight and practical expertise that align with modern scientific approaches to conservation. Integrating such knowledge into formal livestock development policies can enhance breeding strategies, promote biodiversity conservation, and strengthen community participation. The study recommends the establishment of integrated conservation programs, financial and institutional support mechanisms, and a legal framework recognizing traditional livestock management as part of Indonesia's sustainable agricultural development agenda.

Keywords: *Anthropology Of Policy; Ethnozoology; Gayo Buffalo; Sustainable Livestock; Traditional Ecological Knowledge.*

1. Introduction

Indonesia, like many other developing countries, faces significant challenges in ensuring food security while preserving its rich biodiversity. The country has lost a considerable portion of its agricultural genetic resources, underscoring the urgent need for conservation efforts. In this context, the Gayo buffalo (Bubalus bubalis) has emerged as an important local genetic resource, particularly in Aceh, that requires immediate attention and conservation (Maulana et al., 2023). The genetic distinctiveness of such indigenous breeds is increasingly confirmed by molecular studies, such as those using microsatellite markers, which are vital for assessing genetic diversity and formulating conservation plans (Barker, 1994). The Gayo buffalo is more than just a livestock species; it holds deep cultural significance for many communities in Indonesia, especially for the Gayo ethnic group in Aceh. This long-standing relationship has led to the development of a sophisticated ethnotaxonomic system over generations, reflecting the community's profound understanding of their livestock (Uprety et al., 2022).

The Gayo people have developed a nuanced classification system based on horn shape and hide color, correlating with important traits such as endurance, energy output, and meat production (Uprety et al., 2022). Notably, such traditional classifications are increasingly validated by modern genetics; for instance, specific phenotypic traits used in ethnotaxonomy have been shown to correlate with genetic markers, demonstrating the scientific value of indigenous knowledge (Marques et al., 2011). This classification system not only exemplifies the Gayo people's deep knowledge of their livestock but also serves as an integral part of their cultural identity. Integrating traditional knowledge with modern conservation strategies is essential for the sustainable management of the Gayo buffalo population (Maulana et al., 2023). Moreover, similar patterns of alignment between indigenous classification systems and molecular genetics have been reported globally—such as the Maasai's phenotypic cattle groupings in East Africa and the traditional zebu breed distinctions in India—where microsatellite and genomic analyses have verified that community-based classifications correspond closely with underlying genetic structure. These parallels further affirm that ethnotaxonomy is not merely cultural knowledge but a practical, empirically grounded system that complements modern genetic science.

Comparable ethnotaxonomic systems are found in numerous cultures worldwide, demonstrating the broader relevance and scientific validity of indigenous classification practices. Among the Maasai of East Africa, for instance, cattle are systematically categorized according to horn configuration, coat coloration, and characteristic behaviors—traits that correspond with ecological adaptability, disease resistance, and milk productivity. Similarly, pastoral communities in India differentiate zebu breeds using phenotypic markers such as body

morphology and color patterns, which have been shown to align with distinct genetic lineages. In the Philippines, the Ifugao classify carabaos based on physical attributes and functional performance, reflecting generations of selective management adapted to local agricultural needs. These cross-cultural examples illustrate that, much like the Gayo classification system, indigenous livestock taxonomies are grounded in rigorous empirical observation and encode both cultural meaning and practical biological knowledge. Collectively, they highlight a shared global heritage in which traditional ecological knowledge and modern genetic science converge to inform sustainable livestock management.

Moreover, the role of Gayo buffalo in local agriculture extends beyond livestock; they are woven into the social, cultural, and economic fabric of the community (Nasution et al., 2021). Buffalo contribute to food security by providing meat and milk, and they play a vital role in agricultural practices such as tillage and transportation (Maulana et al., 2023). This mirrors the global importance of indigenous livestock, where local breeds are recognized as key assets for sustainable agriculture and rural livelihoods, particularly in Africa and Latin America (Gamborg & Sandøe, 2005). Sustainable management of these animals is critical, particularly in light of increasing pressures from climate change and land degradation that threaten biodiversity and food security (Godde et al., 2021).

Recent studies emphasize the importance of integrating local genetic resources like the Gayo buffalo into broader agricultural strategies to enhance resilience and sustainability (R. Singh et al., 2023). For example, the concept of sustainable intensification highlights the need to boost agricultural productivity while minimizing environmental impacts, achievable through the use of local breeds adapted to specific ecological conditions (R. Singh et al., 2023). Additionally, applying ethnoveterinary practices—utilizing local knowledge of medicinal plants for livestock health—can further enhance the sustainability of buffalo farming in Gayo (Uprety et al., 2022).

Traditional ecological knowledge, particularly the ethnotaxonomy practiced by the Gayo people, is increasingly recognized as a valuable resource in conservation biology and sustainable development. This knowledge system encompasses the classification and understanding of local livestock, often overlooked in formal policy-making processes. As noted by (Malcom, 2024), "integrating indigenous knowledge into livestock policy formulation can enhance the capacity of indigenous communities and policymakers to develop effective livestock management strategies." This approach is supported by genomic studies on water buffalo, which underscore the need to conserve unique genetic lineages identified by both traditional and scientific methods (K. Zhang et al., 2020). The case of the Gayo buffalo presents an opportunity to bridge this gap, combining community wisdom with a scientific approach to livestock management. By acknowledging and incorporating traditional practices, policymakers can devise more effective and culturally relevant strategies for livestock conservation and management.

The Gayo ethnotaxonomy system identifies seven distinct horn shapes and four main skin color categories within their buffalo population. This classification is not merely descriptive; it significantly influences livestock selection, breeding, and utilization. As highlighted by (Darmawan et al., 2023), "the active participation of livestock keepers and the consideration of indigenous knowledge are crucial for the sustainable management of genetic resources". The Gayo people's nuanced understanding of their buffalo, which links horn shape and skin color with traits such as endurance and meat production, exemplifies how traditional knowledge can inform breeding practices. Genomic analyses have begun to confirm the genetic basis for such phenotypic variations, lending credence to traditional breeding selections (K. Zhang et al., 2020) Such insights are vital as Indonesia grapples with potential food insecurity and the loss of local genetic resources, making the conservation of indigenous livestock breeds like the Gayo buffalo increasingly important.

The conservation and sustainable development of indigenous livestock breeds, such as the Gayo buffalo, are essential for maintaining biodiversity and food security. Mapiye et al., (Mapiye et al., 2019) note that "the sustainable use of indigenous cattle genetic resources is crucial for enhancing food security and livelihoods in rural areas". Similar principles apply globally, as seen in the management of Criollo cattle in Latin America, where traditional knowledge is integral to breed conservation and adaptation (Banerjee et al., 2022). Traditional knowledge systems(Nurasri Mulyani et al., 2024), exemplified by Gayo ethnotaxonomy, offer valuable insights that can inform more effective and culturally appropriate livestock policies. By integrating these systems into broader agricultural strategies, it is possible to enhance the resilience of local farming systems while preserving cultural heritage.

This study aims to explore how the ethnozoological knowledge of the Gayo people can be integrated into sustainable buffalo development policies in Aceh. Incorporating indigenous knowledge into livestock management is crucial for fostering sustainable agricultural practices that respect local cultures and enhance biodiversity. By examining the complex relationship between traditional classification systems and livestock traits, this article seeks to provide a framework for policymakers to harness indigenous wisdom in buffalo conservation efforts and breeding programs. Such integration promotes the preservation of genetic diversity and ensures that development initiatives align with the cultural values and practices of the communities they serve (Abas et al., 2022; Suwanamphai et al., 2011).

The Gayo people's ethnozoological knowledge encompasses a wealth of information regarding local buffalo breeds, their traits, and their ecological roles. This traditional knowledge significantly contributes to sustainable livestock management, often including practices that enhance genetic diversity and resilience against environmental changes (Maria, 2018; W. C. Yang et al., 2011). For instance, studies have highlighted the importance of indigenous practices in maintaining the genetic integrity of local buffalo populations, which is essential for their adaptability and productivity(Murni et al., 2020). This is consistent with the FAO's global assessment of animal genetic resources, which advocates for in-situ conservation supported by local knowledge (FAO, 2007a). Furthermore, incorporating local wisdom into educational curricula can empower communities and encourage the next generation to engage in conservation efforts, ensuring the continuity of these valuable practices (Paneru et al., 2021).

Moreover, aligning buffalo development policies with the cultural values of the Gayo people can lead to more effective conservation strategies. Research indicates that when local communities actively manage their natural resources, the outcomes are often more sustainable and culturally relevant (Shah et al., 2016; K. V. Singh et al., 2022) . This participatory approach not only fosters a sense of ownership among community members but also enhances the effectiveness of conservation initiatives by leveraging the unique insights that indigenous knowledge provides (Suwanamphai et al., 2011). Therefore, the proposed framework aims to bridge the gap between traditional ecological knowledge and modern conservation practices, ultimately contributing to the sustainable development of buffalo farming in Aceh.

The integration of Gayo ethnozoology into sustainable buffalo livestock development represents a significant avenue for enhancing agricultural practices while preserving cultural heritage. Ethnozoology, which studies the relationship between humans and animals within specific cultural contexts, can provide valuable insights into sustainable livestock management practices, particularly in regions like Gayo where local knowledge and traditions play a crucial role in animal husbandry.

Gayo buffaloes, recognized for their efficient feed utilization, are an essential genetic resource in Indonesia, particularly in the Bener Meriah Regency. The reproductive characteristics of these buffaloes, as documented by as documented by (Nasution et al., 2023) highlight their potential for sustainable livestock development, emphasizing the need for local breeding programs that align with traditional practices (Nasution et al., 2023). This aligns with the broader discourse on sustainable livestock systems, which advocates for the integration of local genetic resources to enhance resilience and adaptability to environmental changes (R. Singh et al., 2023).

Sustainable livestock practices emphasize the importance of ecological principles in livestock management. For instance, the concept of sustainable intensification, which seeks to increase productivity without adverse environmental impacts, is crucial for regions like Gayo where traditional practices can be harmonized with modern agricultural techniques (R. Singh et al., 2023). The role of herbivores, including buffaloes, in sustainable agriculture is particularly significant, as they contribute to nutrient cycling and soil health, thereby enhancing the overall sustainability of farming systems (Ayantunde et al., 2018).

Moreover, the application of ethnoveterinary practices, which utilize local knowledge of medicinal plants for livestock health, can further support sustainable buffalo livestock development in Gayo. Studies have shown that traditional herbal medicine plays a vital role in livestock healthcare, providing cost-effective alternatives to conventional veterinary practices (Uprety et al., 2022). This is particularly relevant in rural areas where access to modern veterinary services may be limited. By harnessing local knowledge of ethnozoology, farmers can improve animal health and productivity while maintaining ecological balance.

The sustainability of livestock systems also hinges on the socio-economic aspects of farming communities. Research indicates that smallholder mixed crop-livestock systems can encourage sustainable agricultural practices, as they often rely on local resources and knowledge (Rudel et al., 2016). In the context of Gayo, integrating ethnozoological knowledge with sustainable farming practices can empower local farmers, enhance food security, and promote economic resilience (Nasution et al., 2023).

In harnessing Gayo ethnozoology for sustainable buffalo livestock development presents a multifaceted approach that combines traditional knowledge with modern agricultural practices is important. This integration not only supports the sustainability of livestock systems but also preserves the cultural heritage of the Gayo people. Future research should focus on documenting and promoting these practices, ensuring that they are recognized and valued within broader agricultural policies and initiatives.

2. Literature Review

2.1. Conservation of indigenous livestock

The conservation of indigenous livestock genetic resources has become an urgent global priority, particularly in developing countries where rapid agricultural modernization, land-use change, and climate pressures have contributed to the erosion of local breeds. Indonesia exemplifies this trend, having lost a significant proportion of its agricultural genetic resources over recent decades due to breed replacement, habitat degradation, and the expansion of commercial livestock systems(Prihandini et al., 2023). Indigenous breeds, such as the Gayo buffalo (Bubalus bubalis), hold substantial ecological, cultural, and economic value, yet remain vulnerable to declining population sizes and unregulated crossbreeding.

Globally, the Food and Agriculture Organization (FAO) emphasizes that local livestock breeds are irreplaceable reservoirs of adaptive traits shaped by centuries of natural and human selection, contributing to resilience against disease, climatic stresses, and variable feed conditions(FAO, 2007b). These traits make indigenous breeds crucial for sustainable agriculture and food security in rural communities, where production systems often rely heavily on environmental adaptability rather than high-input technologies(Mapiye et al., 2019).

Advances in molecular genetics have strengthened efforts to conserve these resources by enabling precise assessment of genetic diversity and population structure. Microsatellite markers, in particular, have become widely used due to their high polymorphism, codominance, and suitability for analyzing genetic variation within and between livestock populations(Pham et al., 2013). Such tools have revealed that many local buffalo and cattle breeds possess distinct genetic lineages, reinforcing the argument for their conservation and challenging assumptions that indigenous breeds are genetically inferior to commercial or exotic breeds(Saputra et al., 2020).

In the Indonesian context, molecular studies have increasingly confirmed the genetic uniqueness of local buffaloes, highlighting the importance of region-specific conservation strategies. This evidence underscores the need to integrate scientific assessments with local knowledge systems to develop effective conservation policies tailored to the adaptive characteristics and cultural relevance of indigenous livestock. As conservation challenges intensify—driven by climate change, disease outbreaks, and socio-economic pressures—prioritizing the protection of genetic resources like the Gayo buffalo is essential for ensuring long-term agricultural sustainability and rural livelihoods.

2.2. Ethnotaxonomy and traditional ecological knowledge in livestock classification

Ethnotaxonomy, a central component of traditional ecological knowledge (TEK), refers to the culturally grounded systems through which communities classify and understand biological diversity. In livestock-keeping societies, ethnotaxonomic systems are often highly sophisticated, reflecting generations of accumulated empirical observation and cultural transmission. These systems frequently incorporate multiple phenotypic markers—including morphology, coloration, behavior, temperament, and performance—that serve as practical tools for management, breeding, and resource allocation(Berlin, 1992). Unlike scientific taxonomies, which rely on formalized morphological or genetic criteria, ethnotaxonomies integrate cultural meaning with ecological function, thereby offering a holistic perspective on animal diversity.

In Indonesia, ethnotaxonomic systems play a significant role in shaping livestock management practices. Among the Gayo people of Aceh, buffalo classification draws on horn morphology, hide color, and other visible traits that are culturally associated with endurance, strength, and suitability for specific agricultural tasks(S. M. Rahayu et al., 2025). These classifications are not arbitrary; they emerge from long-term experiential knowledge and reflect the community's deep engagement with their environment and animals. Similar systems are seen across other Indonesian ethnic groups, suggesting a broader national reliance on ethnozoological principles in livestock stewardship(ISKANDAR et al., 2025).

Globally, comparative studies show that ethnotaxonomy forms a crucial dimension of indigenous livestock management. Kenya, for example, classify cattle using horn configuration, coat color, and behavioral traits—markers that correlate with ecological adaptability, milk yield, and disease resistance(Butt, 2010). In India, pastoral communities differentiate zebu breeds through body morphology and skin coloration, classifications that have been shown to align with genetically distinct cattle populations(Metta et al., 2004)s. In the Philippines, the Ifugao categorize carabaos according to physical features and work performance, reflecting adaptation to local agricultural systems and cultural preferences(Camacho et al., 2016). These cross-cultural parallels demonstrate that ethnotaxonomic systems consistently encode biologically meaningful information, serving as both cultural expressions and practical management tools.

The growing recognition of TEK within conservation science has prompted scholars to examine how ethnotaxonomic systems contribute to sustainable livestock development. Ethnotaxonomy provides insights into animal behavior, productivity, disease patterns, and ecological interactions—dimensions often overlooked in modern livestock breeding programs. Moreover, because these systems are embedded within cultural practices, they promote conservation outcomes that are socially acceptable and contextually relevant. As such, ethnotaxonomy

represents not only a repository of indigenous knowledge but also a critical resource for contemporary biodiversity management, particularly in regions where formal scientific monitoring is limited.

3. Material and Methods

The use of an ethnographic method in this research offers a valuable lens through which to explore the sustainable development of livestock in Indonesia, particularly in the Gayo Lues District of Aceh. Ethnographic approaches enable researchers to immerse themselves in the community, facilitating a deeper understanding of local practices and beliefs surrounding livestock management. This method has been effectively employed in various studies to reveal the intricate relationships between indigenous knowledge systems and sustainable resource management (Bobo et al., 2015). By utilizing diverse data collection and analysis techniques(Mujanah et al., 2022), this study aims to uncover the rich ethnozoological knowledge of the Gayo people, which encompasses traditional practices, classifications, and uses of livestock that have been developed over generations (Hassan et al., 2022). In this study, the data collection process began from April - September 2024. Informant selection employed a purposive sampling strategy, specifically criterion-based selection, to identify individuals with deep, experiential knowledge of smallholder buffalo farming. The primary criterion for selection was a minimum of 10 years of continuous practical experience in Gayo buffalo husbandry. Initial key informants were identified in collaboration with local agricultural extension officers, and snowball sampling was then used to locate other experienced farmers, ensuring a representation across different sub-districts within Gayo Lues. There were 18 informants from livestock farmers, government officials who handle livestock and community leaders. The findings from the informants were then formulated into issues in the Focus Group Discussion (FGD) involving some stakeholders of buffalo farming in Gayo Lues. The FGD was structured to first present a summary of key themes from the individual interviews, which were then used as discussion points to seek confirmation, elaboration, and collective validation from the group. The FGD comprised 12 participants, including 8 of the initial informants and 4 new stakeholders (e.g., local veterinarians, cooperative representatives) to diversify perspectives. A semi-structured discussion guide was used, and the session was audio-recorded and transcribed verbatim. The synthesis of FGD data involved a qualitative content analysis, where transcripts were coded inductively to identify emergent themes and then compared with the interview data to triangulate findings and arrive at a consensus on the collective knowledge. From them, most of the ethnozoological knowledge of the Gayo people is not only a repository of cultural heritage but also a potential resource for sustainable livestock management. Previous studies have demonstrated that indigenous knowledge can significantly enhance conservation efforts and agricultural practices by providing insights into local biodiversity and ecosystem dynamics (Braga et al., 2019). For instance, Hassan et al. emphasize the importance of understanding the relationship between communities and their natural resources as a foundation for effective conservation strategies (Hassan et al., 2022). For qualitative analysis, all interview and FGD transcripts were analyzed using thematic analysis. This involved a multi-step process of familiarization with the data, generating initial codes, searching for themes, reviewing themes, and defining and naming themes(Sjachriatin et al., 2023). The analysis was conducted manually and cross-checked by two researchers to enhance reliability, with any discrepancies resolved through discussion. This research seeks to contribute to the academic discourse on ethnozoology by highlighting the relevance of traditional ecological knowledge (TEK) in contemporary agricultural practices, thereby bridging the gap between indigenous wisdom and modern sustainability initiatives (Alves et al., 2014).
Moreover, the practical implications of this research extend to policymakers and stakeholders interested in integrating traditional knowledge into modern agricultural practices. By documenting and analyzing the ethnozoological practices of the Gayo people, this study aims to provide actionable insights that can inform policy decisions and development programs. The integration of local knowledge into policy frameworks has been shown to enhance the effectiveness of conservation strategies and promote community engagement in sustainable practices(Ganje et al., 2021). As noted by Svanberg, understanding local food systems and cultural practices is essential for developing strategies that are not only ecologically sound but also culturally appropriate (Svanberg, 2021). Thus, this research aspires to serve as a model for incorporating indigenous knowledge into sustainable livestock development policies in Aceh and beyond.

4. Results

In the rich cultural heritage of Indonesia, the Gayo people in Gayo Lues Regency possess a profound traditional knowledge system regarding buffalo, locally referred to as "koro." This knowledge not only reflects a practical understanding of livestock but also represents a cultural heritage that demonstrates the close relationship between the Gayo people and their buffalo. The general knowledge of the Gayo people about buffalo is typically based on skin color and horn shape.
The Gayo buffalo, scientifically known as Bubalus bubalis or swamp buffalo, genetically possesses 48 pairs of chromosomes. Physiologically, Gayo buffalo are considered to have unique characteristics, which are:

a) Calm Temperament: Gayo buffalo are generally known for their calm and docile nature, making them easy to maintain and manage.
b) Endurance: Gayo buffalo exhibit exceptional endurance in conditions of limited feed, water scarcity, and resistance to parasites like lice and worms.
c) Adaptability: Their superior adaptability to critical environments makes them ideal livestock for areas with challenging environmental conditions.
d) Stamina: Known for their strong energy, they can walk long distances without fatigue and live in groups led by a dominant alpha female (Ulu Tawar).

According to research published by Nasution, et al., (Nasution et al., 2023) the Gayo people have a highly detailed classification system for buffalo based on their horn shape. Each type has its own characteristics and value:

1) Koro Cawing/Gaweng/Kantih

- Distinctive feature: One horn points upward, the other downward
- Gender dominance: Mostly female
- Cultural significance: Considered unique and intriguing
- Rarity: Male Koro Cawing is very rare

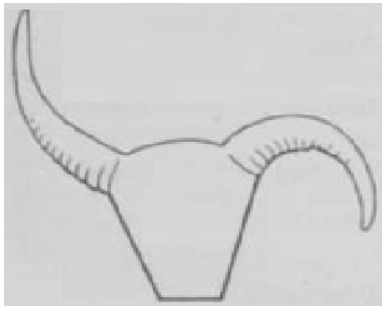

Fig. 1: Koro Cawing/Gaweng/Kantih Horn Shape.

2) Koro Gonok
- Horn morphology: Both horns point downward and/or backward
- Uniqueness: Some individuals have horns that are not firmly rooted
- Special characteristic: The horns may wobble and produce sounds when they collide
- Economic value: Male Koro Gonok has a very high market price

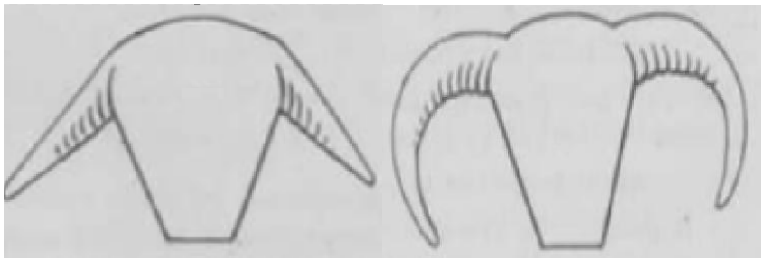

Fig. 2: Koro Gonok Horn Shape.

3) Koro Gampang
- Horn shape: Points upward and widens
- Gender distribution: Balanced between male and female (50:50)
- Color correlation: Often found in jet-black buffalo (Segem)

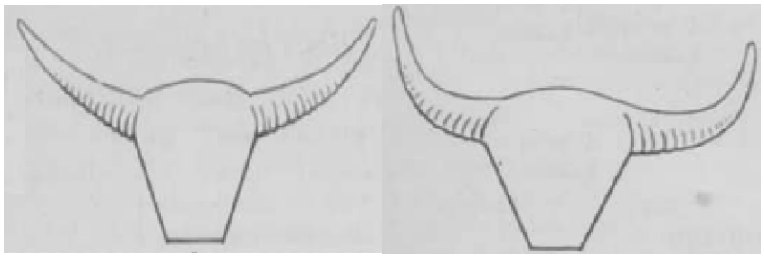

Fig. 3: Koro Gampang Horn Shape.

4) Koro Cakah/Cat or Durung
- Horn characteristic: Points upward without inward curvature
- Gender dominance: Mostly female
- Growth pattern: Horn tips tend to widen while continuing to point upward

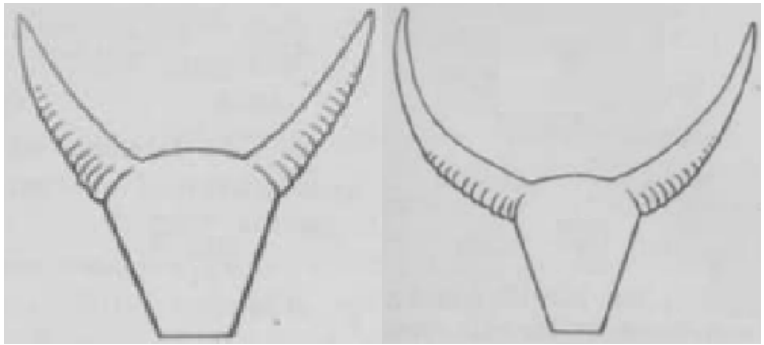

Fig. 4: Koro Cakah/Cat or Durung Horn Shape.

5) Koro Rukup
- Horn shape: Grows backward with curvature
- Local belief: Believed to excel in male combat
- Reason for superiority: The horn shape makes it easier to injure opponents

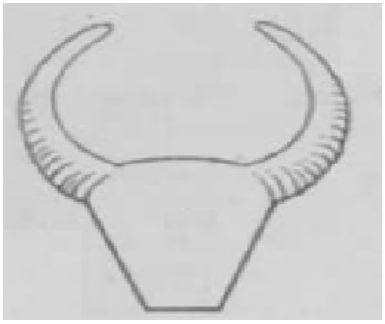

Fig. 5: Koro Rukup Horn Shape.

6) Koro Rebah/Kemiring
- Horn morphology: Grows horizontally to the left and right proportionally
- Gender dominance: Very rare in male buffalo
- Visual characteristic: Provides a unique and easily recognizable appearance

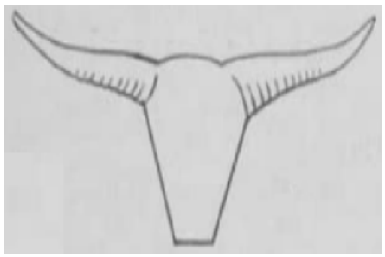

Fig. 6: Koro Rebah/Kemiring Horn Shape.

7) Koro Gupik or Gope
- Uniqueness: No horns or very small horns
- Rarity: Very rarely found among buffalo groups
- Significance: Considered an interesting genetic variation

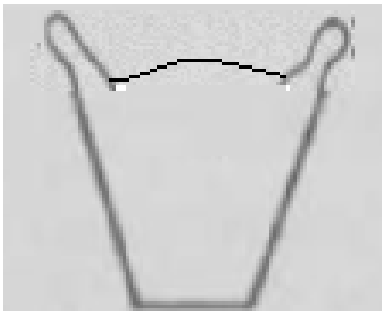

Fig. 7: Koro Gupik or Gope Horn Shape.

In addition to knowledge about buffalo based on horn shapes, the Gayo people also classify buffalo based on skin color. Knowledge of skin color is also an important criterion in the classification of Gayo buffalo. According to research, Gayo buffalo can be categorized by skin color as follows:

a) Koro Segem
- General characteristic: Marked by jet-black skin with a large body posture, solid bone structure, and optimal meat growth.
- Strength: Strong physique, high energy, and higher meat weight (up to 10% heavier than other types of the same age and gender). This buffalo is commonly used as a working animal (pulling loads in forests or fields) and as a meat producer.

b) Koro Jeged
- General characteristic: White skin with a slightly reddish hue. This type is divided into two: one with albino traits, where the eyes are also white, and the other with white skin but black or spotted eyes. The latter is a naturally white-skinned buffalo.
- Characteristics: Slower meat growth and lower physical strength. However, this buffalo has a high market value for traditional ceremonies, and its horns are often ivory-colored (yellow-brown or yellow with black patterns).

c) Koro Impil-impil
- General characteristic: Dark grayish-black or brownish skin. The buffalo's body is often covered with white or reddish-brown hair in certain areas.
- Growth: Approaching the quality of Koro Segem. Its meat production is slightly lower than Segem, making it the second ideal meat producer after Segem.

d) Koro Sawak
- General characteristic: Similar to Impil-impil but with white skin in certain areas, including around the eyes, neck, legs, and abdomen.
- Subcategories:

e) Sawak Bunga: Characterized by a white ring around the eyes. Its meat growth is moderate, making it the third-best buffalo for meat production.

f) Sawak Batu: Features white patterns on the inner front legs and white rings on the neck, back legs, and lower abdomen. Its meat condition and growth are generally the same as Sawak Bunga.

This classification of buffalo by the Gayo people, based on both horn shapes and skin color, reflects a deep understanding of their livestock and offers a unique system for managing and conserving the genetic diversity of Gayo buffalo.

5. Discussion

In the lush landscapes of Aceh, Indonesia, the Gayo buffalo (Bubalus bubalis) exemplifies the intricate relationship between local communities and their livestock. The Gayo people have cultivated a profound understanding of these animals, which is reflected in their sophisticated ethnotaxonomic system. This system categorizes buffalo based on observable traits such as horn shapes and skin colors and embodies a rich repository of traditional ecological knowledge that is crucial for sustainable livestock development policies. Such knowledge systems provide insights into the adaptation of livestock to local environmental conditions, enhancing resilience against climate variability and contributing to food security (Amam, Luthfi, et al., 2024).

The Gayo people's classification of buffalo is more than just cataloging; it integrates physical characteristics with essential traits such as endurance, energy output, and meat production. This ethnotaxonomy identifies several distinct categories of horn shape and hide color, each associated with specific qualities advantageous for various purposes, including work and meat production. In simple terms, the Gayo people's knowledge matrix of buffalo horn shape and hide color combinations can be described as follows:

Table 8: Matrix Combination of Horn Type and Skin Color of Buffalo/Koro associated with Livestock Function

Buffalo/ Koro Horn Shapes and Skin Color	Segem			Jeged			Impil-impil			Sawak		
	Endurance	Energy	Meat	Endurance	Energy	Meat	Endurance	Energy	Meat	Endurance	Energy	Meat
Caweng/ Gaweng	+++	+++	++++	+++	++	+	+++	+++	+++	+++	++	++
Gonok	+++	+++	++++	+++	++	+	++++	++	+++	++++	++	++
Gampang	++++	++++	++++	+++	++	+	++++	+++ +	+++	++++	+++ +	++
Durung/ Cakah	++++	++++	++++	+++	++	+	++++	+++ +	+++	++++	+++ +	++
Rukup	++++	++++	++++	+++	++	+	++++	+++ +	+++	++++	+++ +	++
Rebah	+++	+++	+++	+++	++	+	+++	++	+++	+++	+++	++
Gope/ Gupik	++++	++	++++	+++	++	+	++++	++	+++	++++	++	++

Source: Research Analysis, 2020 updated 2024

Description

\+ = Less Good/Minim

++ = Good

+++ = Good Enough

++++ = Very Good

Based on this matrix, it can be seen that several types of buffalo are preferred for breeding, while others are generally avoided. By referring to this traditional knowledge, the relevance of akain in the context of sustainable livestock development can be seen. Through a technical approach, the most important thing that can be done is to encourage the breeding of buffalo species with maximum value in three aspects. Leveraging local knowledge of livestock farming patterns will emphasize the importance of adaptation and local practices that have developed over generations(Amam, Jadmiko, et al., 2024; Munadi et al., 2021). Furthermore, government policies that support smallholder livestock farming, such as disease control and feed subsidies, play a crucial role in enhancing the effectiveness of these traditional systems (Hadi et al., 2023).

The Gayo buffalo's classification system not only aids in the selection of animals for specific tasks but also reflects a broader understanding of the ecological and economic dimensions of livestock farming. The integration of traditional knowledge with modern agricultural practices can lead to improved livestock productivity and sustainability. For instance, the use of locally adapted breeds, as indicated by the Gayo's ethnotaxonomic practices, can enhance resilience to environmental stresses, thereby ensuring a more sustainable approach to livestock management (Koura et al., 2023). Additionally, the interplay between traditional practices and contemporary agricultural policies can foster a more robust livestock sector that meets the demands of both local and global markets (Soedjana & Priyanti, 2017).

In other word the Gayo buffalo serves as a critical link between the Gayo people's cultural identity and their agricultural practices. The ethnotaxonomic classification of buffalo illustrates the depth of traditional ecological knowledge and highlights its potential contributions to sustainable livestock development policies. By recognizing and integrating these traditional systems with modern agricultural strategies, stakeholders can enhance the resilience and productivity of livestock farming in Indonesia, ensuring food security and sustainable livelihoods for local communities (K. Zhang et al., 2020).

Based on the classification of horn shapes, skin colors, and the orientation of their benefits, Gayo buffaloes have at least three important implications for the Gayo society, as follows:

1) Economic Value

a) The selling price varies based on the combination of horn shape and skin color

b) Some types have special value for traditional ceremonies

2) Practical Use

a) Selection of work animals based on physical characteristics

b) Selection for breeding and meat production

3) Knowledge Heritage

a) The classification system reflects a deep understanding of livestock genetics

b) Knowledge is passed down through generations

The ethnotaxonomy of buffalo in the Gayo community is a complex and highly valuable system of knowledge. The classification based on horn shapes and skin colors not only reflects a practical understanding of livestock farming but is also an integral part of Gayo's cultural

heritage. This system enables the community to effectively select and manage livestock according to their needs and goals, while also maintaining the genetic diversity of local buffalo.

Particular interest is the community's identification of superior buffalo types. Black (Segem) buffalo with specific horn shapes (Gampang, Durung/Cakah, or Rukup) are considered the best overall, balancing endurance, energy, and meat production. This knowledge, passed down through generations, provides a ready-made framework for selective breeding programs aimed at improving buffalo productivity while maintaining genetic diversity. The implications for sustainable livestock development policies are significant, particularly when traditional knowledge is integrated into formal breeding and conservation programs. By recognizing the ethnotaxonomic classifications developed by the Gayo community, policymakers can achieve multiple objectives, including the preservation of diverse local genetic resources, the identification of superior breeding stock, and the tailoring of conservation efforts to buffalo types with desirable traits. This approach aligns with findings that emphasize the importance of integrating traditional ecological knowledge (TEK) into conservation strategies, as it can enhance the effectiveness of biodiversity management and promote sustainable practices (Brooks et al., 2012; Irakiza et al., 2016).

Moreover, promoting traditional husbandry practices that maintain genetic diversity is essential for ensuring the long-term sustainability of the buffalo population. The Gayo community's understanding of their livestock, which includes knowledge of specific traits linked to productivity and resilience, can inform breeding programs that prioritize local adaptations. Such practices not only contribute to the ecological integrity of livestock populations but also support the socio-economic stability of the communities involved (E. S. Rahayu et al., 2020; Riley, 2010). The recognition of traditional knowledge in policy frameworks can facilitate community engagement in conservation efforts, fostering a sense of ownership and responsibility for managing genetic resources (Alemayehu et al., 2022; Waylen et al., 2010).

The value of this ethnozoological knowledge extends beyond productivity; it embodies a cultural heritage that connects the Gayo people to their environment and history. Policies that validate and incorporate this knowledge can strengthen community ties and enhance local stewardship of biodiversity. Successful community-based conservation initiatives often rely on the active participation of local knowledge holders, which can lead to more effective and culturally relevant conservation outcomes (Haenn et al., 2014; Savage et al., 2010). This is particularly relevant in the context of global challenges such as food security and biodiversity loss, where integrating local knowledge with scientific approaches can yield more holistic and effective policies (Sularso et al., 2023; J. Yang et al., 2018).

As we navigate the complexities of sustainable livestock development, the case of the Gayo buffalo in Aceh serves as a compelling model. It illustrates how traditional ecological knowledge can complement scientific methods, resulting in policies that not only meet human needs but also preserve the rich biodiversity and cultural heritage of local communities. By bridging the gap between ancestral wisdom and contemporary conservation practices, stakeholders can create frameworks that enhance both agricultural productivity and ecological sustainability (Fajardo Cavalcanti de Albuquerque, 2020; Gilles et al., 2013).

Based on previous discussions, analytical diagrams can be used to visualize findings and key relationships can be simplified with the following chart:

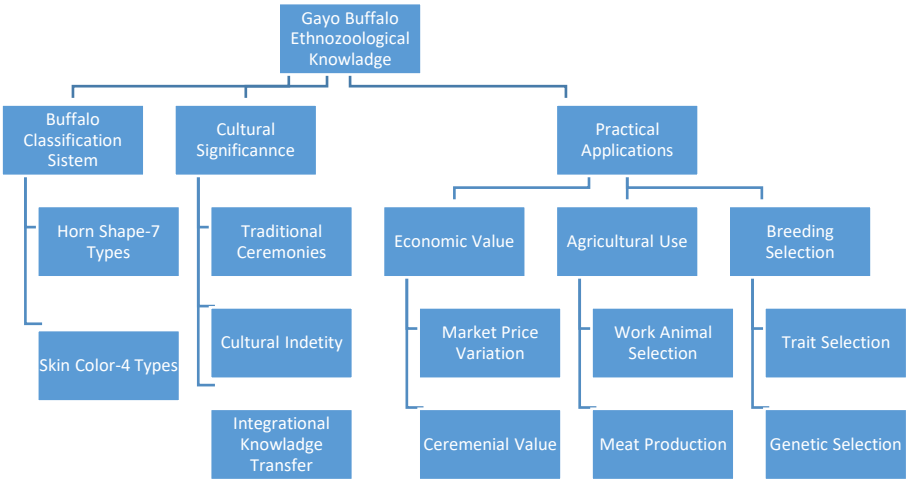

Fig. 9: Diagrams findings about Harnessing Ethnozoology for Sustainable Buffalo Livestock Development in the Gayo Lues.

Source: Research Analysis, 2024.

The ethnozoological knowledge system of the Gayo people regarding buffalo is a complex framework that integrates traditional ecological knowledge with modern scientific understanding. This system reflects a sophisticated approach to livestock management that has evolved over generations, offering valuable insights for contemporary sustainable livestock development policies.

1) Integration of Traditional Knowledge and Modern Practices

The Gayo classification system for buffalo, which is based on observable traits such as horn shapes and skin colors, exemplifies a nuanced understanding of buffalo genetics and phenotypic expression. This traditional knowledge aligns with modern genetic science, particularly in the identification of phenotypic markers. For instance, the correlation between physical characteristics and traits like endurance and meat production suggests that the Gayo people possess an intuitive understanding of genetic markers, akin to findings in other buffalo populations where genetic diversity has been assessed through microsatellite markers (Marques et al., 2011; Uffo et al., 2017). Furthermore, the Gayo's selective breeding practices, which favor specific combinations of buffalo types (e.g., black Segem buffalo with Gampang, Durung/Cakah, or Rukup horns), indicate a sophisticated breeding program that predates modern animal husbandry practices. This is supported by studies showing that traditional breeding methods often reflect deep genetic insights, as seen in the genetic relationships among various buffalo breeds (Joshi et al., 2013; Vijh et al., 2008).

2) Economic Implications

The economic dimension of the Gayo buffalo classification reveals a complex valuation system that influences market dynamics. Different buffalo types command varying market prices, thereby creating a natural incentive for maintaining genetic diversity. This economic

aspect is crucial, as it aligns with findings from other regions where market differentiation based on genetic traits has been shown to support conservation efforts (de Jager et al., 2020; Kathiravan et al., 2009). Additionally, certain buffalo types, particularly those utilized in traditional ceremonies, carry a cultural premium that adds value beyond their practical utility. This cultural significance is echoed in the literature, which highlights how traditional livestock breeds often hold intrinsic value within their communities, thereby reinforcing their economic worth (Groeneveld et al., 2010; Sun et al., 2020).

3) Sustainability Framework

The Gayo buffalo classification system inherently promotes sustainable livestock practices. By recognizing and valuing different buffalo types, the system contributes to the preservation of genetic diversity, a critical factor for resilience in livestock populations. Studies have demonstrated that genetic diversity is essential for the adaptability of livestock to changing environmental conditions (Ali et al., 2022; Y. Zhang et al., 2007). Moreover, the adaptive management aspect of the Gayo classification allows for targeted breeding and selection based on specific needs and environmental conditions, which is a key principle in sustainable livestock management (Tantia et al., 2006). This approach not only enhances the productivity of livestock but also ensures the long-term viability of buffalo populations in the face of ecological changes.

4) Cultural Preservation and Knowledge Transfer

The ethnozoological knowledge system of the Gayo people serves as a repository of cultural heritage, reflecting and preserving their cultural identity. The detailed classification system is not merely a practical tool but also an educational mechanism that facilitates knowledge transfer between generations. This continuity of knowledge is vital for maintaining sustainable practices, as evidenced by studies that emphasize the importance of traditional ecological knowledge in contemporary conservation efforts (Hartoyo et al., 2023; Triwitayakorn et al., 2006). The integration of traditional practices with modern scientific approaches can enhance the effectiveness of livestock management strategies, ensuring that cultural heritage is preserved while adapting to new challenges.

The ethnozoological knowledge system of the Gayo people regarding buffalo represents a sophisticated framework that integrates cultural, economic, and practical dimensions of livestock management. This system not only offers valuable insights for modern sustainable livestock development policies but also underscores the importance of traditional knowledge in contemporary agricultural practices.

6. Conclusion

The Gayo community's ethnozoological knowledge of buffalo has great potential as a framework for sustainable livestock management. This knowledge system uniquely integrates three main aspects: preservation of genetic diversity, economic viability, and cultural preservation. This traditional approach shows how local classification systems can complement modern scientific methods, providing rich insights for community-based livestock development. The survival of local buffalo varieties in this region is highly dependent on the preservation of cultural practices that have been passed down from generation to generation.

In the context of policy development, this ethnozoology-based approach can be realized through several strategic steps. Integrated conservation programs need to be designed to combine the traditional knowledge of the Gayo community with modern scientific approaches, creating a mutually supportive partnership between traditional knowledge holders and animal scientists. In addition, economic support mechanisms can be designed by providing market incentives, such as special certification for traditionally bred buffalo. This will not only preserve local varieties but also increase the economic added value for the community.

Cultural preservation also plays an important role. Traditional knowledge systems need to be systematically documented and digitized so that they are not lost over time. Cultural-based education programs can be a means to ensure intergenerational knowledge transfer. In addition, research and development are needed to validate traditional classification systems through modern genetic analysis and develop breeding programs that combine traditional and scientific methods. To support these steps, policies that recognize traditional breeding practices and establish institutional mechanisms for local communities to contribute to policy-making are essential.

However, the implementation of these integrated policies faces several potential challenges. Securing consistent and adequate funding for long-term conservation and breeding programs remains a primary obstacle, particularly in resource-constrained settings. Limited infrastructure, such as facilities for genetic analysis, veterinary services, and training centers, could hinder the practical application of these programs. Effective stakeholder coordination among various government agencies, research institutions, and local communities is complex and requires clear communication channels and shared objectives to avoid conflicts or duplicated efforts. Furthermore, scaling a certification system for traditionally bred buffalo in remote areas may be challenging due to logistical issues, costs of verification, and the need to build market recognition and trust. A phased, pilot-scale approach to certification, leveraging existing local governance structures and exploring public-private partnerships, could provide a more feasible pathway for implementation under such constraints.

The strategy for implementing the program can start with short-term steps, such as documentation of traditional knowledge and pilot research projects, which then develop into integrated breeding programs and certification systems in the medium term. In the long term, full integration of traditional knowledge into national policies, development of sustainable market mechanisms, and establishment of genetic banks for traditional varieties are the main targets.

Another thing that can be done from these results is the opportunity for further research that concerns at least two things. First, scientific validation of traditional classification systems through modern genetic analysis can strengthen the synergy between science and tradition. This approach not only confirms the accuracy of local knowledge but also provides a scientific basis for wider application. Second, evaluate the effectiveness of traditional buffalo certification programs in improving farmer welfare and genetic conservation. This can provide important insights for the development of conservation-based economic policies. This research is expected to be able to bridge the interests between cultural preservation, environmental sustainability, and local community welfare.

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Conflicts of Interest

The authors declare that they have no financial interests or personal relationships that could have influenced the work reported in this article. All findings, interpretations and conclusions expressed in this research article are entirely the responsibility of the author based on the research. The funding sponsor (Ministry of Education, Culture, Research and Technology of the Republic of Indonesia) had no role in the research design; in the collection, analysis, or interpretation of data; in script writing; or in the decision to publish the results.

Contribution Statement

Conceptualized the research, conducted field investigations, and prepared the original manuscript draft and reviewed the policy analysis framework: AAN
Supervision the research methodology: RHH.
Provided a critical review and validation of aspects of livestock biology, including verification of buffalo classification and genetic characteristics: IS, TSMW
Contribution to the analysis of policy development and socio-cultural framework: MN. Assistance data collection and manuscript editing: II.

References

[1] Abas, A., Aziz, A., & Awang, A. (2022). A Systematic Review on the Local Wisdom of Indigenous People in Nature Conservation. *Sustainability*, *14*(6), 3415. https://doi.org/10.3390/su14063415.

[2] Alemayehu, K., Sara, S., & Addisie, G. (2022). Ethnoecological knowledge allied to the management of wild medicinal plants in Adaa District, East Shewa Zone of Oromia Regional State, Ethiopia. *International Journal of Biodiversity and Conservation*, *14*(1), 35–52. https://doi.org/10.5897/IJBC2019.1311.

[3] Ali, S., Nabi, F., Awais, M., Fareed, S. K., Hussain, J., Adeola, A. C., Khan, R., Ahmed, N., & Quan, G. (2022). Genetic Diversity Relationship in Azakheli Buffalo Inferred from mtDNA and MC1R Sequences Comparison. *BioMed Research International*, *2022*, 1–8. https://doi.org/10.1155/2022/5770562.

[4] Alves, R. R., Silva, V. N., Trovão, D. M., Oliveira, J. V, Mourão, J. S., Dias, T. L., Alves, Â. G., Lucena, R. F., Barboza, R. R., Montenegro, P. F., Vieira, W. L., & Souto, W. M. (2014). Students' attitudes toward and knowledge about snakes in the semiarid region of Northeastern Brazil. *Journal of Ethnobiology and Ethnomedicine*, *10*(1), 30. https://doi.org/10.1186/1746-4269-10-30.

[5] Amam, A., Jadmiko, M. W., Harsita, P. A., & Rusdiana, S. (2024). Formulating a Strategy for Development of Smallholder Beef Cattle Farming in Indonesia with the Force Field Analysis (FFA) Method. *BIO Web of Conferences*, *88*, 00030. https://doi.org/10.1051/bioconf/20248800030.

[6] Amam, A., Luthfi, M., Prihatin, K. W., & Wankar, T. J. (2024). Driving Factors for Sustainable Livestock Development in Indonesia: Study on Beef Cattle Commodities. *BIO Web of Conferences*, *88*, 00031. https://doi.org/10.1051/bioconf/20248800031.

[7] Ayantunde, A. A., Duncan, A. J., van Wijk, M. T., & Thorne, P. (2018). Review: Role of herbivores in sustainable agriculture in Sub-Saharan Africa. *Animal*, *12*, s199–s209. https://doi.org/10.1017/S175173111800174X.

[8] Banerjee, A., Hanna, R., A, B., Satriawan, E., & Sumarto, S. (2022). *Electronic Food Vouchers: Evidence from an At-Scale Experiment in Indonesia*. *6*, 1–23. https://doi.org/10.3386/w28641.

[9] Barker, L. M. (1994). Learning and behavior: A psychobiological perspective. In *Learning and behavior: A psychobiological perspective.* (pp. xxxiii, 535–xxxiii, 535). Macmillan College Publishing Company.

[10] Berlin, B. (1992). *Ethnobiological Classification*. Princeton University Press. https://doi.org/10.1515/9781400862597.

[11] Bobo, K. S., Aghomo, F. F. M., & Ntumwel, B. C. (2015). Wildlife use and the role of taboos in the conservation of wildlife around the Nkwende Hills Forest Reserve; South-west Cameroon. *Journal of Ethnobiology and Ethnomedicine*, *11*(1), 2. https://doi.org/10.1186/1746-4269-11-2.

[12] Braga, H. O., Pereira, M. J., Morgado, F., Soares, A. M. V. M., & Azeiteiro, U. M. (2019). Ethnozoological knowledge of traditional fishing villages about the anadromous sea lamprey (Petromyzon marinus) in the Minho river, Portugal. *Journal of Ethnobiology and Ethnomedicine*, *15*(1), 71. https://doi.org/10.1186/s13002-019-0345-9.

[13] Brooks, J. S., Waylen, K. A., & Borgerhoff Mulder, M. (2012). How national context, project design, and local community characteristics influence success in community-based conservation projects. *Proceedings of the National Academy of Sciences*, *109*(52), 21265–21270. https://doi.org/10.1073/pnas.1207141110.

[14] Butt, B. (2010). Seasonal space-time dynamics of cattle behavior and mobility among Maasai pastoralists in semi-arid Kenya. *Journal of Arid Environments*, *74*(3), 403–413. https://doi.org/10.1016/j.jaridenv.2009.09.025.

[15] Camacho, L. D., Gevaña, D. T., Carandang, †Antonio P., & Camacho, S. C. (2016). Indigenous knowledge and practices for the sustainable management of Ifugao forests in Cordillera, Philippines. *International Journal of Biodiversity Science, Ecosystem Services & Management*, *12*(1–2), 5–13. https://doi.org/10.1080/21513732.2015.1124453.

[16] Darmawan, H., Chang, H.-L., & Wu, H.-H. (2023). A Community-Based Breeding Program as a Genetic Resource Management Strategy of Indonesian Ongole Cattle. *Sustainability*, *15*(7), 6013. https://doi.org/10.3390/su15076013.

[17] de Jager, D., Harper, C. K., & Bloomer, P. (2020). Genetic diversity, relatedness and inbreeding of ranched and fragmented Cape buffalo populations in southern Africa. *PLOS ONE*, *15*(8), e0236717. https://doi.org/10.1371/journal.pone.0236717.

[18] Fajardo Cavalcanti de Albuquerque, M. (2020). Linking agrobiodiversity and culture through the adoption of agroforestry practices: The Agroforestry Indigenous Agents. *Parks Stewardship Forum*, *36*(1). https://doi.org/10.5070/P536146395.

[19] FAO. (2007a). The State of the Food and Agriculture. In *FAO Agricultur* (Vol. 4, Issue 1).

[20] FAO. (2007b). *The State of the World's Animal Genetic Resources for Food and Agriculture*.

[21] Gamborg, C., & Sandøe, P. (2005). Sustainability in farm animal breeding: a review. *Livestock Production Science*, *92*(3), 221–231. https://doi.org/10.1016/j.livprodsci.2004.08.010.

[22] Ganje, J. M. T., Mulima, E. P., & Cristóvão, L. (2021). Ethnozoological Impacts on Fauna Conservation: The Case of Chimanimani National Park. *Journal of Resources Development and Management*. https://doi.org/10.7176/JRDM/76-02.

[23] Gilles, J. L., Thomas, J. L., Valdivia, C., & Yucra, E. S. (2013). Laggards or Leaders: Conservers of Traditional Agricultural Knowledge in <scp>B</scp> olivia. *Rural Sociology*, *78*(1), 51–74. https://doi.org/10.1111/ruso.12001.

[24] Godde, C. M., Mason-D'Croz, D., Mayberry, D. E., Thornton, P. K., & Herrero, M. (2021). Impacts of climate change on the livestock food supply chain; a review of the evidence. *Global Food Security*, *28*, 100488. https://doi.org/10.1016/j.gfs.2020.100488.

[25] Groeneveld, L. F., Lenstra, J. A., Eding, H., Toro, M. A., Scherf, B., Pilling, D., Negrini, R., Finlay, E. K., Jianlin, H., Groeneveld, E., & Weigend, S. (2010). Genetic diversity in farm animals – a review. *Animal Genetics*, *41*(s1), 6–31. https://doi.org/10.1111/j.1365-2052.2010.02038.x.

[26] Hadi, A., Djaha, A. S. A., & Kellen, P. B. (2023). Noetnana Livestock Farmer Group Capacity Building Strategy in Fatukoa Village By Bank Indonesia Representative Office NTT Province Towards Micro, Small and Medium Enterprises (MSMEs) Digital 4.0. *Journal of Tourism Economics and Policy*, *3*(3), 204–218. https://doi.org/10.38142/jtep.v3i3.777.

[27] Haenn, N., Schmook, B., Reyes, Y., & Calme, S. (2014). Improving Conservation Outcomes with Insights from Local Experts and Bureaucracies. *Conservation Biology*, *28*(4), 951–958. https://doi.org/10.1111/cobi.12265.

[28] Hartoyo, A. P. P., Hutagalung, L., Kulsum, F., Sunkar, A., Herliyana, E. N., & Hidayati, S. (2023). SPECIES COMPOSITION, STRUCTURE, AND MANAGEMENT IN GAYO COFFEE-BASED AGROFORESTRY SYSTEM. *Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan (Journal of Natural Resources and Environmental Management)*, *13*(1), 37–48. https://doi.org/10.29244/jpsl.13.1.37-48.

[29] Hassan, M., Haq, S. M., Ahmad, R., Majeed, M., Sahito, H. A., Shirani, M., Mubeen, I., Aziz, M. A., Pieroni, A., Bussmann, R. W., Alataway, A., Dewidar, A. Z., Al-Yafrsi, M., Elansary, H. O., & Yessoufou, K. (2022). Traditional Use of Wild and Domestic Fauna among Different Ethnic Groups in the Western Himalayas—A Cross Cultural Analysis. *Animals*, *12*(17), 2276. https://doi.org/10.3390/ani12172276.

[30] Irakiza, R., Vedaste, M., Elias, B., Nyirambangutse, B., Joram Serge, N., & Marc, N. (2016). Assessment of traditional ecological knowledge and beliefs in the utilisation of important plant species: The case of Buhanga sacred forest, Rwanda. *Koedoe*, *58*(1). https://doi.org/10.4102/koedoe.v58i1.1348.

[31] ISKANDAR, B. S., ISKANDAR, J., MULYANTO, D., & SUPRIATNA, J. (2025). Ethnozoological knowledge of diversity, folk taxonomy, and animal hunting among the Baduy in Banten, Indonesia. *Biodiversitas Journal of Biological Diversity*, *25*(12). https://doi.org/10.13057/biodiv/d251241.

[32] Joshi, J., Salar, R. K., Banerjee, P., S, U., Tantia, M. S., & Vijh, R. K. (2013). Genetic Variation and Phylogenetic Relationships of Indian Buffaloes of Uttar Pradesh. *Asian-Australasian Journal of Animal Sciences*, *26*(9), 1229–1236. https://doi.org/10.5713/ajas.2012.12669.

[33] Kathiravan, P., Mishra, B. P., Kataria, R. S., & Sadana, D. K. (2009). Evaluation of genetic architecture and mutation drift equilibrium of Marathwada buffalo population in Central India. *Livestock Science*, *121*(2–3), 288–293. https://doi.org/10.1016/j.livsci.2008.06.023.

[34] Koura, B. I., Shipandeni, M., & Cutrignelli, M. I. (2023). Sustainable Feeds for Animal Nutrition in Tropical Areas. *Animals*, *13*(8), 1379. https://doi.org/10.3390/ani13081379.

[35] Malcom, A. (2024). Integrating Indigenous Knowledge into Livestock Policy Formulation. *International Journal of Livestock Policy*, *3*(1), 30–42. https://doi.org/10.47941/ijlp.1962.

[36] Mapiye, C., Chikwanha, O. C., Chimonyo, M., & Dzama, K. (2019). Strategies for Sustainable Use of Indigenous Cattle Genetic Resources in Southern Africa. *Diversity*, *11*(11), 214. https://doi.org/10.3390/d11110214.

[37] Maria. (2018). Local wisdom of indigenous society in managing their customary land: a comparative study on tribes in Indonesia. *E3S Web of Conferences*, *52*, 00023. https://doi.org/10.1051/e3sconf/20185200023.

[38] Marques, J. R. F., Martínez, A. M., Costa, M. R., Albuquerque, M. S. M., Quiroz, J., Vega-Pla, J. L., & Delgado, J. V. (2011). Genetic diversity of brazilian buffaloes (Bubalus bubalis) using DNA microsatellites. *Archivos de Zootecnia*, *60*(232), 1213–1221. https://doi.org/10.4321/S0004-05922011000400036.

[39] Maulana, T., Iskandar, H., Said, S., & Gunawan, A. (2023). The Current Status and Potential Development of Genetic Resources of Indigenous Toraya Spotted Buffalo in Indonesia: A Systematic Review. *World's Veterinary Journal*, *13*(4), 617–625. https://doi.org/10.54203/scil.2023.wvj66.

[40] Metta, M., Kanginakudru, S., Gudiseva, N., & Nagaraju, J. (2004). Genetic characterization of the Indian cattle breeds, Ongole and Deoni (Bos indicus), using microsatellite markers – a preliminary study. *BMC Genetics*, *5*(1), 16. https://doi.org/10.1186/1471-2156-5-16.

[41] Mujanah, S., Anshori, M. Y., Rahmalia, D., & Herlambang, T. (2022). Application genetic algorithm to improve transportation problem of cement distribution using Artificial Bee Colony. *AIP Conference Proceedings*, *2577*. https://doi.org/10.1063/5.0096127.

[42] Munadi, L. M., Hafid, H., Aku, A. S., & Abadi, M. (2021). A Reviuw: Sustainable Livestock Development in Indonesia. *Indonesian Journal Of Animal Agricultural Science (IJAAS)*, *3*(2). https://doi.org/10.33772/ijaas.v3i2.18352.

[43] Murni, D., UMIE LESTARI, SRI ENDAH INDRIWATI, ACHMAD EFENDI, NANI MARYANI, & MOHAMAD AMIN. (2020). Morphometric diversity and phenotypic relationship among indigenous buffaloes of Banten, Indonesia. *Biodiversitas Journal of Biological Diversity*, *21*(3). https://doi.org/10.13057/biodiv/d210311.

[44] Nasution, A. A., Harahap, R. H., Suyitman, S., & Hijjang, P. (2023). Ethnotaxonomy of buffallo (Bubalus Bubalis) on livestock system of the Gayo Community, Aceh. *ETNOSIA : Jurnal Etnografi Indonesia*, *8*(2), 257–270. https://doi.org/10.31947/etnosia.v8i2.26099.

[45] Nasution, A. A., Sirojuzilam, Harahap, R. H., & Tafsin, M. (2021). Local Wisdom of Buffalo Farming in the Gayo Community in Gayo Lues Regency, Aceh Province. *Natural Volatiles & Essent. Oils*, *8*(5), 10827 – 10842.

[46] Nurasri Mulyani, Abd. Rahim, Diah Retno Dwi Hastuti, & Citra Ayni Kamaruddin. (2024). Determinants of Catch And Catch Per Unit Effort Of Motorboat And Outboard Motorboat Fishers In Bulukumba Regency. *Demeter: Journal of Farming and Agriculture*, *2*(1), 111–119. https://doi.org/10.58905/demeter.v2i1.229.

[47] Paneru, U., Dhungana, K. P., Kanu, S., & Sharma, P. (2021). Genetic and Non-Genetic Factors on Productive and Reproductive Performance of Indigenous Buffalo. *Journal of Nepal Agricultural Research Council*, *7*, 83–91. https://doi.org/10.3126/jnarc.v7i1.36925.

[48] Pham, L. D., Do, D. N., Binh, N. T., Nam, L. Q., Van Ba, N., Thuy, T. T. T., Hoan, T. X., Cuong, V. C., & Kadarmideen, H. N. (2013). Assessment of genetic diversity and population structure of Vietnamese indigenous cattle populations by microsatellites. *Livestock Science*, *155*(1), 17–22. https://doi.org/10.1016/j.livsci.2013.04.006.

[49] Prihandini, P. W., Tribudi, Y. A., Hariyono, D. N. H., Sari, A. P. Z. N. L., Praharani, L., Handiwirawan, E., Tiesnamurti, B., Romjali, E., Matitaputty, P. R., & Wiyono, A. (2023). Biodiversity of Indonesian indigenous buffalo: First review of the status, challenges, and development opportunities. *Veterinary World*, 2217–2229. https://doi.org/10.14202/vetworld.2023.2217-2229.

[50] Rahayu, E. S., Suharini, E., Fathonah, S., & Maisah, A. (2020). Traditional Knowledge of Banyumas Community about Mesua ferrea as the Identity Plant. *Biosaintifika: Journal of Biology & Biology Education*, *12*(1), 97–103. https://doi.org/10.15294/biosaintifika.v12i1.23834.

[51] Rahayu, S. M., Hakim, L., Batoro, J., & Sukenti, K. (2025). Ethnozoological Study of Animal Consumption by the Sasak Tribe: Implications for Biodiversity Conservation in Lombok, Indonesia. *International Journal of Design & Nature and Ecodynamics*, *20*(6), 1397–1407. https://doi.org/10.18280/ijdne.200620.

[52] Riley, E. P. (2010). The importance of human–macaque folklore for conservation in Lore Lindu National Park, Sulawesi, Indonesia. *Oryx*, *44*(2), 235–240. https://doi.org/10.1017/S0030605309990925.

[53] Rudel, T., Kwon, O.-J., Paul, B., Boval, M., Rao, I., Burbano, D., McGroddy, M., Lerner, A., White, D., Cuchillo, M., Luna, M., & Peters, M. (2016). Do Smallholder, Mixed Crop-Livestock Livelihoods Encourage Sustainable Agricultural Practices? A Meta-Analysis. *Land*, *5*(1), 6. https://doi.org/10.3390/land5010006.

[54] Saputra, F., Jakaria, J., Anggraeni, A., & Sumantri, C. (2020). Genetic Diversity of Indonesian Swamp Buffalo Based on Microsatellite Markers. *Tropical Animal Science Journal*, *43*(3), 191–196. https://doi.org/10.5398/tasj.2020.43.3.191.

[55] Savage, A., Guillen, R., Lamilla, I., & Soto, L. (2010). Developing an effective community conservation program for cotton-top tamarins (Saguinus oedipus) in Colombia. *American Journal of Primatology*, *72*(5), 379–390. https://doi.org/10.1002/ajp.20770.

[56] Shah, M. K., Hayashi, Y., & Kumagai, H. (2016). Productive and Reproductive Performances of Indigenous Lime and Parkote Buffaloes in the Western hills of Nepal. *Journal of Buffalo Science*, *5*(1), 14–17. https://doi.org/10.6000/1927-520X.2016.05.01.2.

[57] Singh, K. V., Das, R., Sodhi, M., & Kataria, R. S. (2022). Morphometric characterisation and performance evaluation of Bhangor indigenous swamp buffalo population of Tripura. *The Indian Journal of Animal Sciences*, *91*(12). https://doi.org/10.56093/ijans.v91i12.119823.

[58] Singh, R., Maiti, S., Garai, S., & Rachna. (2023). Sustainable Intensification – Reaching Towards Climate Resilience Livestock Production System – A Review. *Annals of Animal Science*, *23*(4), 1037–1047. https://doi.org/10.2478/aoas-2023-0027.

[59] Sjachriatin, E., Riyadi, S., & Mujanah, S. (2023). The effects of knowledge-oriented leadership style, digital transformation, and human resource development on sustainable competitive advantage in East Java MSMEs. *Uncertain Supply Chain Management*, *11*(4), 1685–1694. https://doi.org/10.5267/j.uscm.2023.6.021.

[60] Soedjana, T. D., & Priyanti, A. (2017). Competitiveness of Indonesian Livestock Production among ASEAN Countries. *Indonesian Bulletin of Animal and Veterinary Sciences*, *27*(1), 1. https://doi.org/10.14334/wartazoa.v27i1.1411.

[61] Sularso, S., Jazuli, M., Djatiprambudi, D., & Hanshi, B. (2023). Revitalizing cultural heritage: Strategies for teaching Indonesian traditional music in elementary schools. *International Journal of Education and Learning*, *5*(1), 79–88. https://doi.org/10.31763/ijele.v5i1.1016.
[62] Sun, T., Wang, S., Chanthakhoun, V., Dang, R., Huang, Y., Chen, H., & Lei, C. (2020). Multiple domestication of swamp buffalo in China and South East Asia. *Journal of Animal Breeding and Genetics*, *137*(3), 331–340. https://doi.org/10.1111/jbg.12445.
[63] Suwanamphai, S., Chantachon, S., Paengsoi, K., & Thongwol, N. (2011). Conservation and Developing Indigenous Knowledge of Using Water Buffaloes. *Journal of Social Sciences*, *7*(2), 146–148. https://doi.org/10.3844/jssp.2011.146.148.
[64] Svanberg, I. (2021). The Importance of Animal and Marine Fat in the Faroese Cuisine: The Past, Present, and Future of Local Food Knowledge in an Island Society. *Frontiers in Sustainable Food Systems*, *5*. https://doi.org/10.3389/fsufs.2021.599476.
[65] Tantia, M. S., Vijh, R. K., Mishra, B., Kumar, S. T. B., & Arora, R. (2006). Multilocus Genotyping to Study Population Structure in Three Buffalo Populations of India. *Asian-Australasian Journal of Animal Sciences*, *19*(8), 1071–1078. https://doi.org/10.5713/ajas.2006.1071.
[66] Triwitayakorn, K., Moolmuang, B., Sraphet, S., Panyim, S., Na-Chiangmai, A., & Smith, D. R. (2006). Analysis of Genetic Diversity of the Thai Swamp Buffalo (Bubalus bubalis) Using Cattle Microsatellite DNA Markers. *Asian-Australasian Journal of Animal Sciences*, *19*(5), 617–621. https://doi.org/10.5713/ajas.2006.617.
[67] Uffo, O., Martínez, N., Acosta, A., Sanz, A., Martín-Burriel, I., Osta, R., Rodellar, C., & Zaragoza, P. (2017). Analysis of microsatellite markers in a Cuban water buffalo breed. *Journal of Dairy Research*, *84*(3), 289–292. https://doi.org/10.1017/S0022029917000425.
[68] Uprety, Y., Karki, S., Poudel, R. C., & Kunwar, R. M. (2022). Ethnoveterinary use of plants and its implication for sustainable livestock management in Nepal. *Frontiers in Veterinary Science*, *9*. https://doi.org/10.3389/fvets.2022.930533.
[69] Vijh, R. K., Tantia, M. S., Mishra, B., & Bharani Kumar, S. T. (2008). Genetic relationship and diversity analysis of Indian water buffalo (Bubalus bubalis). *Journal of Animal Science*, *86*(7), 1495–1502. https://doi.org/10.2527/jas.2007-0321.
[70] Waylen, K. A., Fischer, A., Mcgowan, P. J. K., Thirgood, S. J., & Milner-Gulland, E. J. (2010). Effect of Local Cultural Context on the Success of Community-Based Conservation Interventions. *Conservation Biology*, *24*(4), 1119–1129. https://doi.org/10.1111/j.1523-1739.2010.01446.x.
[71] Yang, J., Wang, Y.-C., Wang, D., & Guo, L. (2018). Application of Traditional Knowledge of Hani People in Biodiversity Conservation. *Sustainability*, *10*(12), 4555. https://doi.org/10.3390/su10124555.
[72] Yang, W. C., Tang, K. Q., Mei, J., Zeng, W. B., & Yang, L. G. (2011). Genetic diversity analysis of an indigenous Chinese buffalo breed and hybrids based on microsatellite data. *Genetics and Molecular Research*, *10*(4), 3421–3426. https://doi.org/10.4238/2011.December.5.1.
[73] Zhang, K., Lenstra, J. A., Zhang, S., Liu, W., & Liu, J. (2020). Evolution and domestication of the Bovini species. *Animal Genetics*, *51*(5), 637–657. https://doi.org/10.1111/age.12974.
[74] Zhang, Y., Sun, D., Yu, Y., & Zhang, Y. (2007). Genetic diversity and differentiation of Chinese domestic buffalo based on 30 microsatellite markers. *Animal Genetics*, *38*(6), 569–575. https://doi.org/10.1111/j.1365-2052.2007.01648.x.