Exploring the Integration of Traditional Ecological Knowledge with Artificial Intelligence to Mitigate Human-Wildlife Conflict in Kerala, India

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Abstract. Increasing human-wildlife conflict (HWC) in forest-fringe landscapes necessitates innovative and culturally acceptable mitigation strategies. This note proposes integrating Traditional Ecological Knowledge (TEK) with Artificial Intelligence (AI) to mitigate HWC in Kerala. The proposition aims to translate African rural traditional knowledge of using alarm calls of Guinea fowls (*Numida meleagris*) as an intelligent technonatural alarm system to alert to the presence of wild animals. The hybrid AI system posits a low-cost, culturally acceptable alert mechanism and a livelihood-embodied coexistence model worth pilot experimentation.

INTRODUCTION

Human-wildlife conflict (HWC) precipitates as a result of the increasing efforts by either party to meet their needs. Such conflicts are increasing in the forest-fringe areas of Kerala, India [1]. Habitat fragmentation [2], urban expansion [3], climate change [4] and the intensification of agricultural practices [5] are the major factors ascribed to the increased episodes of HWCs. Institutional responses to HWC in the state include fencing, culling, or relocation of intruding wild animals [6]. They often fail to provide long-term relief and are reported to disrupt the ecological balance [7]. The diminishing returns of conventional and technological strategies deployed to mitigate HWC in the state portray an increasingly insecure future.

The payoffs of stand-alone conventional HWC mitigation strategies are limited by the unpredictability of man-animal interactions, the adaptability of wild animals, and the operational challenges of maintaining perpetual alertness. A multi-pronged approach that concurrently addresses the above limitations will be a big step in addressing HWC. Integrating Traditional Ecological Knowledge (TEK) with Artificial Intelligence (AI) is a promising means to increase the returns on investment and avert HWCs in Kerala. TEK represents a deep-rooted, community-based understanding developed over generations by indigenous and local communities. It encompasses insights into animal behaviour, seasonal patterns, ecological cues, and survival strategies that have been refined through proximate observation and experience [8]. AI embodies data-driven synthetic intelligence. Together they provide a pragmatic pathway that is scientifically sound, technically feasible and culturally adaptable.

In the context of human-wildlife interactions, TEK often holds vital information about the movement patterns of animals, the signs of impending attacks, or the presence of predators. For instance, in several African and Asian communities, birds, insects, and even plant responses are considered indicators of ecological change or animal activity [9–11]. Modern science is only beginning to appreciate the knowledge embedded in cultural practices, which offers a form of 'natural intelligence'. Despite its richness in context and nuance, TEK lacks systematic documentation and is constrained by scalability issues. These restrict their use in policy and large-scale conservation strategies.

Integrating TEK with AI systems helps to overcome scalability limitations. AI serves as an empowering ally, rendering transformative potential to traditional knowledge. Built on machine learning and neural networks, AI systems excel at identifying hidden patterns across multiple scenarios (datasets) that are often intuitively deciphered by indigenous communities. When applied to HWC, AI can analyse real-time sensor inputs, images, and acoustic signals to warn about lurking predators and automate response mechanisms [12,13]. However, these systems require large volumes of labelled data, contextual calibration, and human oversight to function effectively in real-world settings. Without a grounding in local ecology and social involvement, stand-alone AI systems risk false positives, misinterpretations, and technological alienation among the communities they aim to serve.

The integration of TEK and AI presents a synergistic model for HWC mitigation. For instance, if a community is aware that a specific bird call is an alert about leopard movement in a region, that information can guide the design of AI models trained to recognise and act upon that call. Furthermore, the inclusion of local knowledge in AI development fosters trust, ensuring that the resulting technologies are not perceived as intrusive or alien. Involving communities also help in long-term maintenance, feedback loops, and ethical governance of AI systems.

A pragmatic example of TEK-AI integration is the proposal to utilise Guinea fowls as natural alarm systems in the forest fringes of Kerala, India. Inspired by the traditional African practice of using Guinea fowls as sentinel birds, the authors are exploring the possibility of coupling this behavioural knowledge with an AI-powered acoustic alarm system. It demonstrates how an intelligent, self-sufficient, affordable, and culturally integrated early warning system against HWC can be developed by utilising the indigenous knowledge of bird behaviour.

The potential for decentralisation and democratisation of HWC management is the larger significance of TEK and AI integration. This method enables communities to co-create innovations that reflect their lived realities, rather than relying on top-down interventions. By integrating indigenous knowledge systems with state-of-the-art science and validating them, this approach also enhances ecological stewardship. It is crucial to preserve, honour, and incorporate human cultural intelligence as we enter a future that is increasingly influenced by artificial intelligence. The combination of TEK and AI is more than a technical fix. It reflects an idea of co-creation and co-existence.

HUMAN-WILDLIFE CONFLICT IN KERALA, INDIA

In Kerala, human-wildlife conflict (HWC) has become a significant socio-ecological concern in recent years, primarily due to habitat fragmentation, increasing pressure on forest ecosystems, and the expansion of human settlements into wildlife territories [1]. Spread north-south along the biodiverse stretch of the Western Ghats, Kerala is home to a wide variety of flora and fauna. While the robust forest cover and protected areas contribute significantly to biodiversity conservation, they precipitate a debated boundary between human livelihood zones and wild habitats.

As forest corridors shrink and agricultural and residential zones expand into buffer regions, the frequency of direct encounters between humans and wildlife grows alarmingly. Districts such as Wayanad, Palakkad, Idukki, and Pathanamthitta have consistently reported rising incidents of crop raiding, livestock depredation, property damage, and human casualties. Among the most frequently reported HWCs in Kerala are wild boar intrusion into agricultural fields, followed by pachyderm raids that destroy banana plantations and homes and leopard attacks that endanger livestock. Incidents of elephants maiming human lives are also on the rise. Once considered timid, the behaviour of porcupines has also changed. They face humans nonchalantly. A classic illustration of the vast distances traversed by wild animals in search of resources was the sighting of a wild buffalo on the Digital University campus in 2024.

Terrain and demographic features of the state exacerbate HWC. Kerala has one of the highest population densities in India and is characterised by a continuous human settlement that extends from urban to rural and forest edges. With agriculture being the primary livelihood option for the majority of the rural masses, people residing in the forest fringes bear the brunt of HWC. For small-scale farmers, even a single instance of crop raid can result in a significant loss of income for the entire season. The collective insecurity and frustration of a society that experiences repeated HWCs manifest as disenchantment towards wildlife conservation initiatives and sporadic retaliatory actions against animals.

The state government and other non-governmental organisations have implemented several measures to address the crisis. These include trench digging, CCTV surveillance, drone monitoring, electric fencing, solar-powered fencing, and compensation plans for impacted parties. While these approaches offer respite, they all have scalability challenges. Trenches are effective in arresting elephant movement. However, other predators cross them. It is not pragmatic to build and maintain trenches along the entire forest fringes. The cost of installing and maintaining electric fences is prohibitive. Financial compensation for human lives and livelihoods lost is a stopgap arrangement. Geographic remoteness restricts the deployment of stand-alone technological interventions, such as drones and camera trap surveillance. Furthermore, these solutions are generally implemented in a top-down manner and do not involve communities in active monitoring or decision-making.

Participatory warning systems to mitigate HWCs remain overlooked in Kerala. The onus is on the state to search for solutions to HWC at the intersection of ecology and equity, tradition and technology. Focus should be on ingeniously harnessing social will to evolve technonatural participatory models of early-warning systems. The shift from reactive to preventive will inspire frontline communities to come forward voluntarily with contextual innovations that pave the way for coexistence.

From Africa to Forest Edges in Kerala: A Cross-Cultural Adaptation of TEK

Guinea fowls are used by rural communities as natural intruder detection systems in many regions of sub-Saharan Africa. In addition to being extremely watchful during the day, these birds are renowned for having keen hearing at night, which allows them to detect even slight disturbances. They are instantly alerted to intruding animals and strangers and react with distinctive alarm calls that immediately rise to a chorus [14,15]. These birds are raised in African households not only as poultry but also as reliable nocturnal guardians. They are widely referred to as "the eyes and ears of the homestead".

Rationale for the TEK-AI Integrated Model for HWC Mitigation

The seeds of transformation are often cloaked to appear irrelevant. This philosophy underpins the exploration of an idea drawn from African traditional knowledge, which utilises Guinea fowls as living acoustic alarm systems in HWC-prone landscapes of Kerala. The authors propose a TEK-AI integrated solution to amplify the alarm calls of Guinea fowls in addressing the HWC challenge in the forest fringes of Kerala. This proposition stems from the following traits that make them ideal for use as bioacoustic sentinels:

- Guinea fowls adapt well to humid tropics.
- Loud, characteristic alarm calls of the species that are triggered by auditory cues, especially at night.
- Flock synchronisation: One bird's alarm rapidly escalates into communal outcry.
- Roosting vigilance: Guinea fowls roosting on elevated perches continue to monitor their surroundings in low-light conditions.
- Innate predator detection sense developed by co-evolving with wild threats.
- Low maintenance cost, disease resistance, and minimal housing requirements.

These attributes qualify Guinea fowls as first responders in acoustic surveillance, alerting humans to intrusions long before they visually detect danger.

TEK-AI Integrated Model for HWC Mitigation in Kerala

The authors propose an intelligent system that recognises the alarm calls of Guinea fowls and scales it to alert residents in the vicinity. The system includes:

- Microphones positioned near the roosting area to detect alarm calls.

- An AI model to separate the alarm calls of the Guinea fowls from other sounds
- Scaling network to alert the residents in the vicinity to the alarm calls.
- SMS or mobile call alerts to appropriate authorities for the rollout of predefined Standard Operating Procedures (SOP).

Such a hybrid technonatural approach will extend the range and reliability of the natural alarm system, especially during late night hours when human alertness is low and animal movement is high. The fusion of biological sensors (Guinea fowls) with electronic signal boosters could serve as a low-cost, off-grid solution, especially valuable in remote and forest-edge communities.

LIVELIHOOD, EMPOWERMENT, AND LOCAL ADAPTATION

The proposed TEK-AI system stretches beyond human security. It has the potential for socioeconomic transformation. Pilot-tested and scaled, this initiative could evolve into a community-based livelihood program with the following benefits:

- Micro-enterprise units for breeding and selling Guinea fowls.
- Poultry meat and egg production, offering nutritional and economic support.
- Youth employment in bioacoustic training, bird care, and system maintenance.
- Women-led self-help groups manage the bird rearing and alarm systems.

The integration of security with livelihood ensures community participation and long-term sustainability. The system provides a responsive, non-lethal, and culturally acceptable alternative, particularly in areas with infrastructure challenges. Moreover, their dual-day-and-night activity ensures round-the-clock monitoring, a feature even canines or most electronic sensors struggle to offer consistently.

THE PILOT

To operationalise the TEK-AI integrated solution, the authors recommend a multi-disciplinary pilot in an HWC-prone region that includes:

1. Behavioural Trials: Introduce Guinea fowls in test villages, observe responses to controlled wildlife stimuli.
2. Tech Integration: Deploy prototype sound amplification units to assess sound propagation, false positives, and community response time.
3. Ecological Assessment: Ensure no displacement of native avifauna and minimal risk of disease introduction.
4. Community Training: Conduct workshops on bird care, acoustic interpretation, and basic electronics for amplification systems.
5. Impact Metrics: Measure wildlife incident reduction, alert response time, crop/livestock loss prevention, and community perception.

If the pilot demonstrates a high correlation between vocalisations and predator presence, the solution can be scaled to other regions**.**

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