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Indigenous Knowledge and Climate Resilience in Lao Agriculture

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Abstract

The accelerating frequency and severity of climatic hazards place agricultural systems and food security under significant threat, particularly in vulnerable nations like Lao PDR. Indigenous Knowledge (IK) is increasingly recognized as a vital repository of place-based strategies for climate change adaptation. However, the efficacy of this knowledge against unprecedented, non-historical climate variability remains a critical research gap. This study provides a qualitative assessment of the agricultural IK system in Northern Laos, aiming to 1) identify and document the existing components of IK, 2) assess its functional contribution to climate resilience, and 3) explore stakeholder perceptions of its contemporary importance. We employed a mixed-methods case-study design in Houaypaen village, Luang Prabang. Data were collected via participatory focus group discussions (N = 16) and in-depth interviews (N = 6) with age-stratified farmers, supplemented by a key informant survey (N = 16) of government, INGO, and CSO representatives. Qualitative data were thematically analyzed, and all datasets were triangulated. The findings document a sophisticated, three-pillar IK system: 1) a multi-scalar climatic prediction system using bio-indicators and fauna; 2) nature-based agricultural techniques, including vegetation-based soil classification and ecologically-permeable bamboo weirs; and 3) the maintenance of climate-tolerant, short-duration crop varieties. Critically, we identified a primary community vulnerability: a significant "adaptation-response gap". Farmers expressed high confidence in IK for proactive, long-term seasonal adaptation but reported low confidence and limited knowledge for reacting to acute, high-impact disasters like flash floods. Stakeholder perceptions mirrored this gap; while IK was rated as "vital" (4.0/5.0 mean importance), 50% of respondents argued it is now insufficient alone, leading to a unanimous call for integration. This study concludes that while the local IK system provides a robust foundation for adaptive capacity to known variability, it is ill-equipped for coping capacity against extreme events. This necessitates a policy shift from passive preservation to the active, functional integration of IK with modern science, particularly in developing "co-created" hybrid early warning systems.

Keywords

Indigenous Knowledge, Climate Change, Climate Resilience, Adaption, Lao Agriculture

1. Introduction

The accelerating frequency and severity of global climatic hazards constitute one of the most significant existential threats to contemporary food systems, placing agricultural production and food security under acute pressure worldwide (Anderson, Bayer, & Edwards, 2020). This threat is particularly pronounced in vulnerable nations such as the Lao PDR, where subsistence and small-scale rain-fed agriculture remain pivotal to livelihoods and national economic stability (Phompila, Lewis, Ostendorf, & Clarke, 2017). The Lao PDR has consistently prioritized agriculture in its development plans, aiming to eradicate hunger and promote sustainable farming in alignment with the Sustainable Development Goals. However, climatic variability, manifested through prolonged droughts, unpredictable rainfall patterns, and intensified extreme weather events like floods, severely compromises these national objectives, leading to low yields, reduced productivity, and economic loss (Apraku, Morton, & Gyampoh, 2021; Benhin, 2008; Faling, 2020). The challenge is especially critical for smallholder farmers who lack the financial and technological capacity for large-scale, modern adaptation, leaving them highly exposed to climate shocks (Aksa, 2020; Benhin, 2008).

In response to this escalating vulnerability, Indigenous Knowledge (IK) has emerged as a vital and resilient repository of localized, place-based strategies for adapting to environmental change (Apraku et al., 2021; Datta, Datta, Lewis, & Hurlbert, 2024; Elia, Mutula, & Stilwell, 2014; Ijatuyi, Lamm, Yessoufou, Suinyuy, & Patrick, 2025; Zvobgo, Johnston, Olagbegi, Simpson, & Trisos, 2023). For centuries, local communities, including those in Laos and across the African Sahel, have cultivated sophisticated knowledge systems transmitted orally across generations, relying on empirical observation of bio-indicators like plant phenology, animal behavior, and celestial bodies to forecast seasonal weather and manage risk (Aksa, 2020; Balehegn, Balehey, Fu, & Liang, 2019; Benhin, 2008; Ijatuyi et al., 2025; Loupessis et al., 2025). This traditional ecological knowledge provides an intimate understanding of local ecosystems, guiding critical agricultural decisions like planting timing, crop selection, and traditional conservation techniques (Ali, Shah, Alotaibi, Ali, & Khan, 2025; Anderson et al., 2020; Ankrah, Kwapong, & Boateng, 2022; Datta et al., 2024; Ijatuyi et al., 2025; Zvobgo et al., 2023). The functional significance of IK is widely recognized, affirmed by research underscoring its critical role in resilience, especially where conventional climate information is inaccessible or unreliable (Apraku et al., 2021; Barzegar, Ghorbani, Moghaddamnia, & Rahimi, 2025; Benhin, 2008; Elia et al., 2014; Faling, 2020).

Despite the consensus on the importance and resilience-building potential of traditional knowledge (Loupessis et al., 2025), a significant research and policy challenge remains: the efficacy of inherited IK systems against unprecedented, non-historical climate variability is uncertain (Barzegar et al., 2025; Datta et al., 2024; Elia et al., 2014; Faling, 2020). While Indigenous Knowledge is highly effective for gradual, proactive adaptation to known, recurrent climate patterns (Balehegn et al., 2019; Elia et al., 2014; Ijatuyi et al., 2025), its capacity to cope with acute, high-impact disasters—such as flash floods or extreme heat events that exceed historical memory—is increasingly questioned by scholars and stakeholders (Barzegar et al., 2025; Elia et al., 2014; Ijatuyi et al., 2025; Loupessis et al., 2025; Zvobgo et al., 2023). This phenomenon, characterized by a robust "adaptation" capacity but a weak "coping" capacity, represents a critical knowledge gap that must be addressed to ensure genuine community resilience in the face of rapidly escalating climate change. Furthermore, previous studies in Lao PDR have highlighted the fading of traditional farming practices in certain regions, signaling a potential loss of this vital knowledge base (Ijatuyi et al., 2025; Zvobgo et al., 2023).

Therefore, this study offers a rigorous, qualitative assessment of the agricultural Indigenous Knowledge system in Northern Laos, focusing on Houaypaen village, Luang Prabang. The overall objective is to identify IK's role in addressing climate change impacts and its perceived importance. To achieve this, the study addresses three specific research objectives: 1) document existing IK components; 2) assess its functional contribution to climate resilience (adaptation and impact mitigation); and 3) explore stakeholder perceptions of IK's importance for contemporary agriculture. We employed a mixed-methods case-study design utilizing participatory focus group discussions, in-depth interviews with age-stratified farmers, and a key informant survey of governmental and non-governmental stakeholders. These findings will inform a necessary policy shift from passive preservation toward active, functional co-creation and integration of IK with modern science for developing hybrid early warning and disaster response systems. In this context, "co-creation" extends beyond simple combination; it represents a collaborative process where Indigenous and scientific knowledge systems are integrated as complementary assets to generate hybrid solutions (Ijatuyi et al., 2025). This approach aims to bridge the gap between local ecological wisdom and meteorological data, ensuring that adaptation strategies remain robust against unprecedented climate variability (Zvobgo et al., 2023).

2. Study Site

The selected study area is Houaypaen village, situated in the northern region of Luang Prabang, Pakou district, approximately 56 kilometers north of Luang Prabang city (as shown in **Figure 1**). Positioned in a lowland area surrounded by lush green forest, the village boasts abundant natural resources, including wildlife and arable land. A significant river flows around the village, serving as a vital resource for agricultural activities, fishing, and the collection of natural river vegetables. The village's economy originally relied on subsistence agriculture, but a shift toward market-oriented practices occurred in the 1990s following the government's introduction of the New Economic Mechanism (NEM). This shift was accompanied by an increase in local trading facilitated by Road 13. Local traders, equipped with trucks, began collecting and purchasing products from the village, transporting them to markets in Luang Prabang city and Vientiane capital. The rise of tourism in Luang Prabang town in 1999 further fueled the demand for agricultural products, leading to rapid agricultural development in the village. As the demand increased, local farmers expanded their agricultural areas, diversified crops, and adopted new technologies such as tractors, grass cutters, water pump machines, cement infrastructure, rice mills, and later, fertilizers and rice harvest machines. Foreign Direct Investment (FDI) entered the village in the 2000s during the peak of cash crops like maize and cassava.

Education in the village faces challenges, with limited promotion of children's education. Most residents complete high school in neighboring villages, and only a few pursue higher education, settling in cities. The village has a primary school, and after completing primary education, students must travel to neighboring villages for higher grades. Despite the absence of a hospital, the village has dedicated village nurses providing basic healthcare services to the residents.

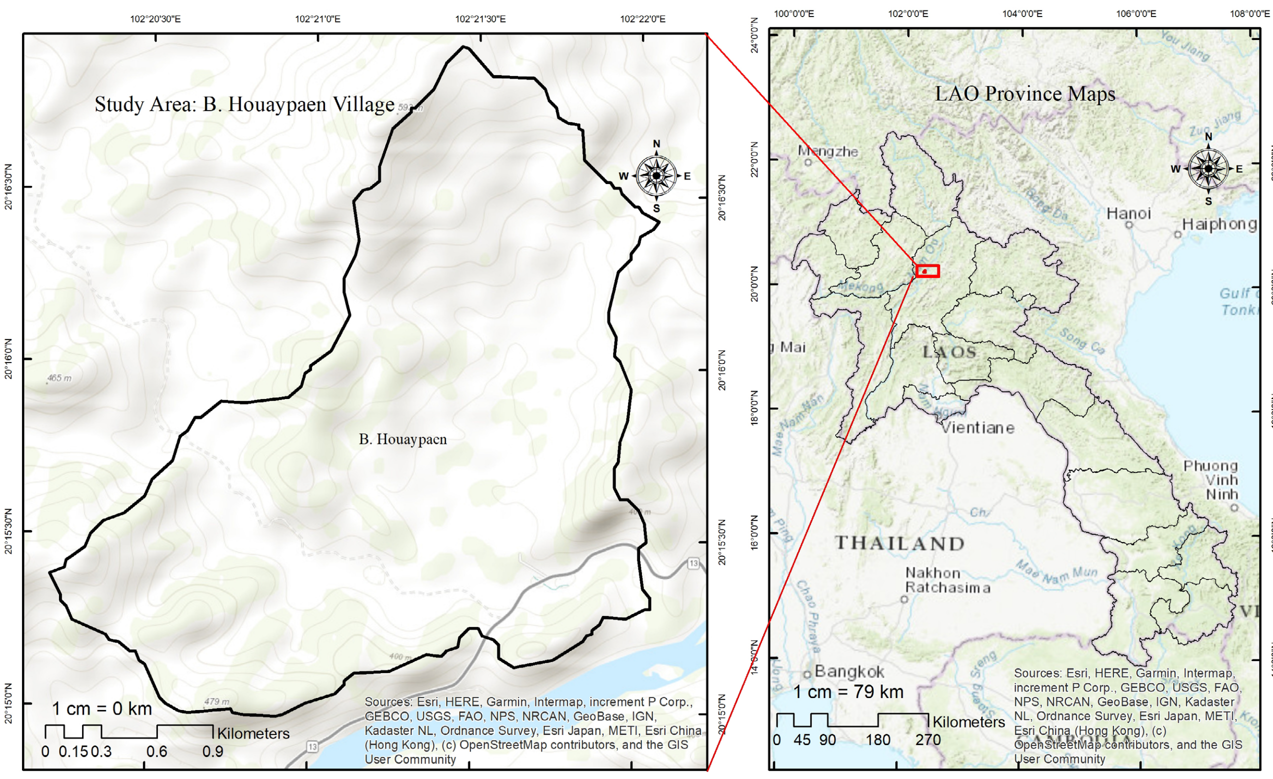

Figure 1. A village location in the northern Laos.

3. Research Methodology

The conceptual framework (as shown in Figure 2) posits that stakeholder perceptions are fundamental to leveraging Indigenous Knowledge (IK) for agricultural climate resilience. The effective application of IK—conceptualized here as a synthesis of traditional ecological observation, predictive skills, established agricultural management practices, and the cultivation of resilient, tolerant crop varieties—is hypothesized as a direct driver. This application, in turn, is expected to enhance key climate resilience outcomes. These outcomes include improved adaptive capacity, more effective disaster risk management, and the promotion of sustainable ecological systems and biodiversity. The model suggests a pathway from perception to knowledge application to resilience. The main research objectives were to identify IK in agriculture that contributes to adaptation and biodiversity protection and conservation. With the aim of a capturing insight and good understanding, the research employed a qualitative methodology, utilizing various methods to collect data in the field, including focus group discussions, in-depth interviews, site observations, and surveys.

This study employed a qualitative, mixed-methods approach. The primary method was Focus Group Discussions (FGDs), which provided a holistic view of indigenous agricultural knowledge through group interaction. These findings were supported and validated by semi-structured In-Depth Interviews (IDIs) that allowed for deeper probing.

Site observations were conducted to gather direct, contextual evidence of the landscape, practices, and related infrastructure. Finally, a structured interview guide was used to systematically assess key stakeholder perceptions of IK's importance, complementing the other qualitative data.

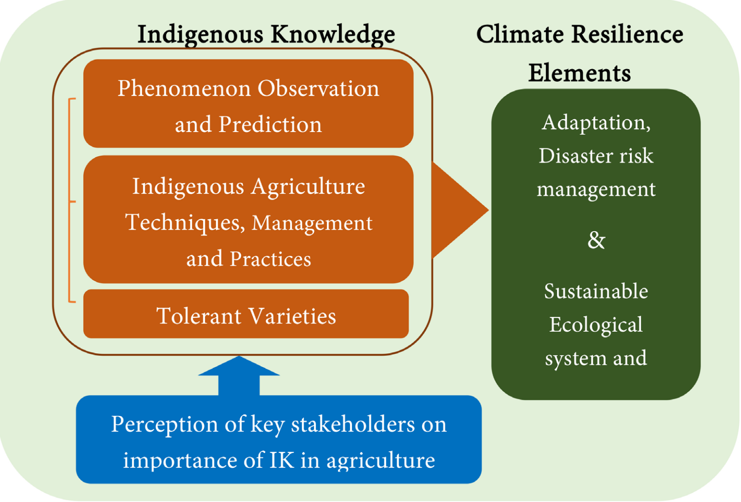

Figure 2. Research conceptual framework.

The combination of these methods aimed to provide a comprehensive understanding of indigenous knowledge in agriculture concerning climate change adaptation and biodiversity protection and conservation. The participatory nature of focus group discussions, coupled with the flexibility of in-depth interviews and the observational insights, contributes to a nuanced and multifaceted exploration of the role of indigenous knowledge in building resilience in the face of climate change in agriculture. More details are explained below:

3.1. Population and Sampling

This research utilized purposive sampling within a specific community, targeting participants central to understanding climate change adaptation. The sample included local farmers, government representatives, and staff from INGOs and CSOs engaged in climate resilience initiatives.

To ensure comprehensive data on Indigenous Knowledge (IK), farmer sampling was dynamically stratified into elderly, middle-aged, and youth groups. This captured the full spectrum of IK, from long-term experience to the integration of new information. Inclusivity was prioritized by involving men, women, and individuals with disabilities.

Government and NGO/CSO staff from relevant sectors (e.g., agriculture, environment) contributed survey data on the perceived importance of IK. The study design aimed to gather qualitative data through 6 in-depth interviews with farmers and 16 participants in focus group discussions, supplemented by 16 surveys with institutional stakeholders.

3.2. Research Instruments

3.2.1. Focus Group Discussion (FGD)

Focus Group Discussions (FGDs) served as the primary method to explore community-held Indigenous Knowledge (IK). The objective was twofold: to understand the characteristics and impacts of local climate hazards and to identify the specific IK applied to mitigate these events. This investigation was structured around the conceptual framework's key areas, including traditional early warning systems, agricultural management techniques, and tolerant crop varieties.

Facilitation utilized a participatory approach adapted from Care International's Climate Vulnerability and Capacity Analysis (CVCA) tool, modified with supplemental probing questions. This method fostered intensive discussion and practical exercises, promoting a collaborative environment to generate deeper insights. The facilitator and research team captured detailed notes throughout these sessions to ensure comprehensive data collection.

3.2.2. In-Depth Interview with Farmers

Building on insights from the Focus Group Discussions (FGDs), in-depth interviews (IDIs) were employed to capture nuanced individual perspectives and ensure a comprehensive community-level understanding of Indigenous Knowledge (IK). The semi-structured interview guide was systematically developed to align with the core research objectives and the study's conceptual framework, adhering to social science research principles. Guiding questions were designed to probe the framework's key components:

– Observation and Prediction: Exploring traditional methods for observing phenomena to predict weather, crop suitability, and seasonal calendars as part of local early warning systems.
– Agricultural Techniques: Investigating indigenous practices and management strategies, including climate-resilient infrastructures, that facilitate adaptation to environmental changes.
– Tolerant Varieties: Documenting the identification and utilization of local crop varieties that demonstrate tolerance to climate change and associated hazards.

This method allowed for a detailed examination of individual knowledge, complementing the collective data gathered during the FGDs.

3.2.3. Observation

Direct observation, conducted through transect walks, served as a supplementary data collection method. This approach provided crucial firsthand insights into the local agricultural context, focusing specifically on the design and construction of farm infrastructure. Key areas of observation included the characteristics of lowland rice paddies and the implementation of weir systems for water management. This yielded a tangible understanding of the physical elements supporting the community's agricultural practices and contributing to their resilience strategies.

3.2.4. Interviewed Question Guide

To ascertain the perspectives of key stakeholders regarding the significance of Indigenous Knowledge (IK), a structured interviewed question guide was employed. The questionnaire aimed to explore fundamental information, including the types of climatic and environmental hazards experienced in the community. Additionally, it sought to identify existing indigenous knowledge within the community, focusing on its application in agriculture, specifically in lowland and highland cultivation. The questionnaire delved into the documentation of successful cases where indigenous knowledge had been effectively utilized.

Furthermore, the questionnaires were designed to extract insights into how key stakeholders perceive the importance of indigenous knowledge. Stakeholders were prompted to share their perspectives on promoting and enhancing indigenous knowledge within the communities, with the ultimate goal of bolstering community resilience. This approach facilitated a comprehensive understanding of the stakeholders' viewpoints and attitudes toward indigenous knowledge in the context of climate resilience.

3.3. Instrument Design and Validation

The research instrument was developed by adapting established qualitative methodologies to align with the study's specific objectives. A mixed-method approach was employed, integrating surveys, semi-structured interviews, and Participatory Rural Appraisal (PRA) techniques, including focus group discussions and seasonal calendars. This combination was strategically chosen to effectively gather and triangulate data on Indigenous Knowledge (IK).

The primary aim of these methods was to capture local knowledge and perceptions relevant to climate change adaptation. Key areas of inquiry focused on changes in rainfall patterns, traditional weather forecasting, resilient native crop varieties, and the indigenous timing and location of agricultural practices. This approach facilitated a comprehensive understanding of how IK is applied to enhance community resilience.

All data collection tools were created under supervision from the National University of Laos (NUOL). To ensure validity, the instruments underwent rigorous pre-testing: interview and discussion guides were piloted with six farmers, while surveys were tested with three INGO stakeholders. The tools were subsequently refined based on participant feedback before full implementation.

3.4. Data Collection

This study employed a mixed-methods design to triangulate data, integrating qualitative and quantitative techniques. The primary methods included semi-structured in-depth interviews, Focus Group Discussions (FGDs), field observations, and survey questionnaires. Data collection in the target village was completed during an intensive three-day field mission.

A 2.5-day FGD was conducted with 16 participants, selected to ensure diverse perspectives. This group represented various age categories (5 elders, 8 middle-aged, 3 youth) and geographical locations within the village, all of whom regularly exchange agricultural information. The facilitated discussions focused on climate hazards, indigenous knowledge, and tolerant crop varieties. Key points were documented on flipcharts and continuously clarified by the researcher to ensure accuracy.

The remaining half-day of fieldwork was dedicated to in-depth interviews with 6 local farmers (two from each age category). These interviews largely confirmed the knowledge shared in the FGD, suggesting a high degree of communal information sharing within the small village. Concurrent field observations provided contextual insights into existing agricultural infrastructure, tools, and management practices.

To capture broader stakeholder perceptions of indigenous knowledge, a survey was designed using Microsoft-365 forms. This was distributed to 16 key stakeholders at district, provincial, and national levels, yielding 16 responses. The respondent pool comprised 6 government officials, 5 INGO staff, 4 CSO staff, and 1 private sector representative. Finally, follow-up calls with key stakeholders were conducted for data validation and to gain deeper perspective.

3.5. Data Analysis

Data analysis utilized an inductive coding process to thematically categorize qualitative data, aligning community-sourced results with research objectives. For quantitative survey data, initial platform-based analysis was supplemented with a more comprehensive PivotTable analysis in Excel. To construct the narrative report, the researcher triangulated multifaceted data streams, integrating findings from village fieldwork (interviews, FGDs), key informant surveys, and direct observations. This analytical process was iterative, involving ongoing communication with farmers and respondents for clarification. Upon completion, all findings were subjected to a final validation step, confirming interpretations via online calls with both local farmers and survey participants.

4. Results

This study initial documents the comprehensive Indigenous Knowledge (IK) system used for agricultural resilience, detailing its components from ecological prediction to crop management (4.1). It then identifies a critical vulnerability termed the "adaptation-response gap", highlighting that while IK excels at proactive seasonal adaptation, it is ineffective against acute disasters (4.2). Finally, stakeholder analysis confirms this gap, revealing a unanimous consensus that IK, while vital, is now insufficient alone. Stakeholders strongly recommend a "co-creation" model, integrating IK with modern science to address future climate challenges (4.3).

4.1. Indigenous Knowledge in Practice: Prediction, Management, and Varieties

Local farmers utilize a comprehensive Indigenous Knowledge (IK) system for agricultural resilience. This includes ecological prediction, nature-based soil and water management, resilient cultivation systems, and the preservation of climate-tolerant crop varieties. More details are:

1. Climatic Prediction and Early Warning: Indigenous Knowledge (IK) is fundamental to local agricultural planning and risk assessment, operating on both long-term (annual) and short-term (immediate) temporal scales. Annual forecasting relies on the Lao astrological calendar for a baseline prediction of rain, drought, and animal disease. This outlook is refined using specific bio-indicators observed during the land preparation period for highland cultivation. Flora-based indicators are crucial for seasonal planning. The timing of the rainy season is predicted by the fruiting location on the Ficus Hispida (fig tree); fruit on the lower, middle, or upper trunk signals an early, mid-season, or late onset of rain, respectively. This method is reportedly highly accurate. Rainfall quantity is forecasted by examining the Caesalpinia mimosoides Lam pods—more numerous and larger seeds indicate a wetter year. Fauna provides both immediate and long-term cues. A local taxonomy of flying termites predicts short-term conditions: "rainy flying termites" (Mao Fon) emergence suggests ongoing drizzle, whereas "dry flying termites" (Mao Laeng) signal several days of dry weather. For annual forecasts, Weaver ant (Oecophylla smaragdina) nest height is correlated with wind. Low nests predict low-flowing wind, which is interpreted as an indicator of higher livestock disease risk for the year. Immediate forecasts utilize atmospheric and physiological indicators. A solar or lunar halo warns of heavy rain or a heatwave, while a red sky specifically predicts hail. Furthermore, a widely corroborated physiological cue involves human scar tissue; individuals with old, severe injuries report feeling distinct itchiness in their scars one to two days before a significant weather change (e.g., from rain to sun).

2. Agricultural Techniques and Management: Based on ecological forecasts, farmers deploy a range of nature-based agricultural strategies. Soil fertility is assessed using vegetation as a primary indicator. For example, the presence of a Pa Khok (dry dipterocarp) forest identifies infertile, pebble-mixed soil (Din Kaem Hae), which farmers reserve for specific drought-tolerant, short-duration rice varieties like Khao Met Noi. In contrast, lush bamboo forests signal fertile black clay or silt soils (Din Dak Dam/Din Dam), suitable for more nutrient-demanding crops. This ecological knowledge allows for precise crop-to-soil matching, optimizing yields and conserving resources. For sustainable water management, traditional bamboo weirs are commonly used for lowland irrigation. While modern concrete is more durable, farmers note that the semi-permeable bamboo structures are more ecologically beneficial. They allow a controlled flow of water downstream, which helps conserve river biodiversity and creates a habitat for fish and other aquatic life, supplementing local food sources. Resilient cultivation systems are also key. Highland farming employs a 3 - 4 year rotational shifting cultivation, allowing the forest and soil to regenerate naturally. This is integrated with multicropping, where a single plot often contains 6 - 8 different crops (e.g., rice, chili, peanuts) to enhance household food security and diversify risk. Finally, to protect the harvest from rain and wind during the extended manual threshing period, farmers stack rice sheaves in a distinct, tightly packed conical "bud-shape", an indigenous design that effectively sheds water and provides structural stability.

3. Climate-Tolerant Varieties: Additionally, local farmers demonstrate clear adaptive strategies in crop variety management. There is a strong community preference for short-duration rice (Khao Dau), maturing in three months, over long-duration varieties (Khao Pii). This is an explicit risk-management strategy to minimize crop exposure to late-season droughts and floods. Furthermore, farmers maintain seed sovereignty by selecting, cleaning, drying, and storing their own seeds from each harvest. This practice ensures seed security, reduces external dependency, and preserves genetic diversity specifically adapted to the local environment.

4.2. The Adaptation-Response Gap: A Primary Vulnerability

A central finding is the "adaptation-response gap", which defines the community's primary vulnerability. This gap represents a clear distinction between the high effectiveness of Indigenous Knowledge (IK) for long-term, proactive adaptation and its low effectiveness in responding to acute, short-term disasters. Farmers expressed high confidence in IK for seasonal planning. Their knowledge systems for soil management, variety selection, and cultivation practices are robust and empirically tested within the local environment. This allows them to proactively adapt agricultural strategies to predicted climate patterns, such as shifting to drought-tolerant rice varieties in an anticipated dry year. Conversely, farmers reported low confidence and limited knowledge for managing acute, catastrophic events like severe flash floods, intense storms, or novel hazards. When faced with such events, which cause near-annual damage, their primary recourse is often just to monitor the situation. The few disaster-response practices available are frequently belief-based, such as rituals intended to halt storms or floods. These are applied with significant uncertainty regarding their efficacy, as noted by community members. This finding highlights a critical vulnerability: while the community's long-term planning is adaptive, its capacity to cope with extreme events that exceed historical norms is severely limited.

4.3. Stakeholder Perceptions on Indigenous Knowledge

A survey of key stakeholders from government, INGOs, and CSOs confirmed both the value and present challenges of Indigenous Knowledge (IK). Stakeholders overwhelmingly view IK as vital for agricultural resilience, awarding it an average importance rating of 4.0 out of 5.0. This strong consensus was clear, with 12 of the 16 respondents rating it as "very" or "most" important. Despite this agreement on importance, stakeholders were divided on IK's current effectiveness, reflecting the adaptation-response gap.

Figure 3. Local farmers discuss about climate hazards, adverse impact and how they use IK to handle and how IK effectively contributes to mitigate the climate impact, especially identifying native rice varieties to adapted to the climate change. Photos were taken during field data collections, April 2023.

Half believed existing practices help farmers cope, while the other half argued IK is becoming insufficient against the escalating severity and pace of climate change. This division led to a unanimous call for integration, with all respondents asserting that IK must be blended with scientific evidence and embedded in formal policies. Stakeholders strongly recommended a hybrid approach focused on the "co-creation" of new knowledge. Key proposals included promoting further research, establishing community learning platforms, facilitating dialogue between farmers and scientists, and mainstreaming relevant IK into primary school curricula to ensure its intergenerational transmission (as shown in **Figure 3** and **Figure 4**).

Figure 4. Small home gardens of local farmers next the rice field. Photos were taken during field data collections, April 2023.

5. Discussion

This study's findings confirm that the Houaypaen community possesses a sophisticated and multi-faceted Indigenous Knowledge (IK) system for agricultural resilience, detailing its application in ecological prediction, resource management, and crop selection. The central finding, however, is the identification of a critical "adaptation-response gap", which represents the primary vulnerability of this system. While community IK provides robust, high-confidence strategies for proactive seasonal adaptation, it is perceived by farmers as largely ineffective for reacting to acute, catastrophic disasters. This gap is mirrored in the perceptions of key stakeholders, who, despite universally valuing IK, are divided on its present-day effectiveness, leading to a unanimous call for a hybrid "co-creation" model that integrates IK with modern science.

The documentation of this comprehensive IK system aligns with a growing body of evidence on the significant contribution of indigenous knowledge to climate change adaptation (Petzold, Andrews, Ford, Hedemann, & Postigo, 2020). The detailed practices, such as soil classification by vegetation and the use of bioindicators, affirm that IK is a dynamic, experience-based science, as described by (Aksa, 2020; Apraku et al., 2021; Balehegn et al., 2019; Barzegar et al., 2025; Benhin, 2008; Ijatuyi et al., 2025). However, the "adaptation-response gap" introduces a critical nuance. It suggests that while IK is highly evolved for managing known historical variability, it is ill-equipped to handle the unprecedented intensity and frequency of modern climate hazards. This finding supports the stakeholders' concern that IK, while essential, is becoming insufficient on its own and may help explain the fading of traditional practices observed by (Laing et al., 2018; Newby, Manivong, & Cramb, 2013) in other Lao contexts.

The primary implication is that policy and development interventions must move beyond the simple preservation of IK and toward its active, functional integration with scientific knowledge. The unanimous stakeholder call for a hybrid approach provides a clear mandate for developing "co-created" solutions. To operationalize the "co-creation" model, policymakers should prioritize establishing local climate service forums where scientific forecasts are downscaled and cross-referenced with community bio-indicators (Ijatuyi et al., 2025). Additionally, funding must be directed toward participatory action research to develop hybrid early warning systems specifically designed to bridge the identified "adaptation-response gap" (Zvobgo et al., 2023). These concrete interventions would move beyond passive preservation, effectively functionally integrating local ecological wisdom with modern meteorological science to enhance coping capacities against extreme events (Barzegar et al., 2025).

This study was, however, limited by its qualitative, single-village case study design; therefore, its findings are context-specific and not broadly generalizable. The stakeholder survey, while insightful, was also limited by its small sample size. Future research should focus on quantitatively validating the accuracy of the documented bio-indicators against meteorological data. Furthermore, action-research projects should be initiated to design and pilot hybrid early warning systems that directly address the "adaptation-response gap" by blending scientific forecasting with local predictive knowledge. Comparative studies in other regions of Laos would also be valuable to determine if this gap is a widespread phenomenon.

Furthermore, the reliance on purposive sampling introduces a potential selection bias that must be acknowledged. By targeting participants identified as "central" to agricultural decision-making, this study likely captures the upper echelon of ecological literacy within the community. Consequently, the findings may represent a "best-case" scenario regarding proactive adaptation, masking a potentially wider competency gap among the general population who may lack such specialized knowledge. This reinforces the concerns regarding the erosion of traditional practices noted by (Newby et al., 2013). Moreover, it is plausible to speculate that the "adaptation-response gap" identified here is not unique to Northern Laos but reflects a broader global challenge. As climate anomalies increasingly exceed the historical baselines upon which traditional forecasting is founded, similar discrepancies between adaptation and coping capacities are likely present in other IK-dependent regions, such as the African contexts described by (Apraku et al., 2021; Balehegn et al., 2019).

6. Conclusion

This qualitative study provides robust evidence of a sophisticated, multi-faceted Indigenous Knowledge (IK) system for agricultural resilience in Northern Laos. The primary contribution of this research is the identification of a critical "adaptation-response gap", which constitutes the community's principal vulnerability. Our findings demonstrate that while the local IK system—encompassing ecological prediction, nature-based resource management, and the curation of tolerant crop varieties—provides a high-confidence framework for proactive, long-term adaptation to historical climate variability, it is perceived by farmers as largely ineffective for reactive coping with acute, unprecedented disasters. This gap signifies that IK, as a standalone strategy, is becoming insufficient to manage the escalating frequency and intensity of modern climate hazards. This empirical finding is corroborated by stakeholder perceptions, which, despite valuing IK as vital, revealed a consensus that it can no longer meet these challenges alone. The unanimous call from all stakeholder groups for a hybrid, "co-creation" model provides a clear policy and research directive. We conclude that enhancing climate resilience in this context requires a strategic shift beyond the passive preservation of IK. The imperative is to foster the active, functional integration of indigenous and scientific knowledge. This "co-created" approach is essential to address the documented coping deficit and develop robust, hybrid strategies—particularly in early warning and disaster response—capable of meeting future climate challenges.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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