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Integrating Community-Based AI with Local Knowledge for Sustainable Water Governance: A Case from the Osing People

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ABSTRACT

Water scarcity is an escalating concern, especially in rural and indigenous regions where ecological vulnerability intersects with institutional weakness. This study investigates how Artificial Intelligence (AI) can be integrated with the Sustainable Livelihoods Approach (SLA) to enhance water governance among the Osing indigenous people in Banyuwangi, East Java. Using a mixed-method, multi-site design—including interviews, focus groups, and participatory observations—the research explores how local knowledge, social capital, and institutional structures shape community responses to AI-based interventions. Findings show that while AI offers predictive potential, its success hinges on epistemic justice and cultural contextualization. Villages with strong social and financial assets, such as Olehsari, exhibit greater readiness for AI integration, whereas others face barriers including low digital literacy, weak infrastructure, and limited trust. A hybrid model of community-based AI is proposed, combining algorithmic tools with indigenous ecological indicators and participatory design processes. The study contributes to the growing discourse on inclusive technology by demonstrating that sustainable water governance requires co-produced knowledge systems, where local and scientific epistemologies interact symmetrically. The integration of AI and SLA offers a replicable framework to address water challenges in indigenous communities without marginalizing their knowledge and identity.

Keywords: *sustainable livelihoods, artificial intelligence, indigenous knowledge, epistemic justice, water governance, Osing community*

INTRODUCTION

In Banyuwangi Regency, East Java, water governance issues are not merely technical concerns but intersect deeply with cultural, ecological, and institutional dimensions. The Osing community, indigenous to the region, has long practiced sustainable water management rooted in spiritual and customary values—such as the ritual of 'selametan air' and the communal protection of springs (belik). However, in recent years, pressures from land conversion, tourism expansion, and top-down infrastructure development have begun to erode these traditions. Cases from villages like Kemiren and Olehsari show that conflicts over spring access, decreased water discharge, and the introduction of unfamiliar digital technologies without community consultation have triggered public resistance and institutional fragmentation. These local phenomena illustrate the broader tension between externally imposed water management models and localized ecological wisdom.

This study is theoretically guided by three interconnected perspectives. First, Anthony Giddens(1986)' structuration theory provides a lens to analyze the recursive relationship between institutional structures (such as technology systems and governance norms) and the agency of indigenous communities. Second, the Sustainable Livelihoods Approach (SLA)(Chambers and Conway, 1992), emphasizes community resilience based on asset-based adaptation across five capitals—natural, human, social, physical, and financial. Third, the concept of epistemic justice (Fricker, 2007) is used to critically reflect on how knowledge systems interact, recognizing that indigenous knowledge often faces marginalization within technocratic development paradigms. These theories collectively underpin the analysis of how AI technologies intersect with local ecological ethics, institutional practices, and power dynamics in community-based water governance. First, Anthony Giddens' structuration theory provides a lens to analyze the recursive relationship between institutional structures (such as technology systems and governance norms) and the agency of indigenous communities. Second, the Sustainable Livelihoods Approach (SLA) emphasizes community resilience based on asset-based adaptation across five capitals—natural, human, social, physical, and financial. Third, the concept of epistemic justice (Fricker, 2007) is used to critically reflect on how knowledge systems interact, recognizing that indigenous knowledge often faces marginalization within technocratic development paradigms. These theories collectively underpin the analysis of how AI technologies intersect with local ecological ethics, institutional practices, and power dynamics in community-based water governance.

Indonesia, like many other developing countries, is facing increasingly complex water challenges due to rapid environmental degradation, weak governance, and socio-cultural neglect. In recent years, tensions have emerged between national infrastructure development projects and community-based ecological practices, particularly in rural and indigenous areas. For instance, conflicts surrounding spring protection in Java and dam development in Kalimantan have raised alarms about the marginalization of local wisdom in state-driven water governance agendas. By 2022, more than two billion people worldwide experience severe water shortages at least one month per year (UN Water, 2023). Meanwhile, 80% of global wastewater remains untreated, and more than half of the world's watersheds are significantly degraded (WWAP, 2022). These facts reveal that water crises are not solely technical or ecological problems, but deeply rooted in governance failures, distributional injustice, and institutional weaknesses (Ostrom, 1990; Pahl-Wostl, 2008). at least one month per year (UN Water, 2023).. Meanwhile, 80% of global wastewater remains untreated, and more than half of the world's watersheds are significantly degraded (WWAP, 2022). These facts reveal that water crises are not solely technical or ecological problems, but deeply rooted in governance failures, distributional injustice, and institutional weaknesses (Ostrom, 1990; Pahl-Wostl, 2008).

In rural and indigenous areas, these challenges intensify due to layered social vulnerabilities. Banyuwangi Regency, East Java, is one such example. Here, the Osing community—including villages like Olehsari, Kemiren, Kenjo, and Paspan—maintains strong water-related cultural values. Water (belik) is revered not only as a basic need but also as a spiritual and social symbol. Practices such as source almsgiving, forest protection around springs, and collective water management are integral to their ecological ethics. However, pressures from climate change, land conversion, and externally imposed development models have increasingly disrupted this harmony. The introduction of technologies without cultural adaptation often leads to conflict between local knowledge systems and technocratic logic. One of the most notable examples is Artificial Intelligence (AI), now widely applied in water resource management for prediction, monitoring, and automation (Kumar et al., 2020; Shen, 2024).

While AI holds significant potential, its top-down deployment in indigenous contexts often clashes with deeply rooted knowledge systems. Resistance to AI does not stem solely from digital illiteracy or infrastructure deficits but reflects epistemic tensions—a dissonance between algorithmic universality and situated local knowledge. Current literature in AI and conservation tends to emphasize efficiency and automation but underexplores how such technologies interface with traditional values and institutions. Simultaneously, the Sustainable Livelihoods Approach (SLA) has been applied to understand community resilience and resource management, yet is rarely integrated with AI-driven systems.

In Osing villages, deploying AI without participatory mechanisms can marginalize adaptive local institutions and traditional knowledge, a phenomenon sometimes described as digital colonialism. Therefore, sustainable technological integration must embrace epistemic justice, enabling ethical dialogue between modern innovations and indigenous worldviews. Given these challenges, this study aims to explore how SLA and AI can be combined into a hybrid, community-based water governance framework. Specifically, it investigates the social, ecological, and institutional dynamics shaping the adaptation and acceptance of AI among the Osing people in four villages in Banyuwangi. Through this lens, the research contributes to designing more inclusive, ethical, and context-sensitive conservation technologies.

Accordingly, this study investigates how Artificial Intelligence (AI) can be ethically and effectively integrated into community-based water governance among indigenous populations—particularly the Osing people—by aligning technological systems with local knowledge and sustainable livelihoods. It examines the socio-ecological and institutional factors that shape community responses to AI-based water conservation, explores how epistemic tensions arise between algorithmic logic and indigenous ways of knowing, and seeks to identify a hybrid governance model that enables co-production of knowledge and culturally grounded adaptation. Through this inquiry, the research aims to generate a context-sensitive framework that ensures AI technologies support, rather than undermine, the ecological ethics and social institutions of indigenous communities.

Theoretical Framework

To understand the complex dynamics in the integration of artificial intelligence (AI) technology with the livelihood system of the Osing indigenous community in water conservation, this study uses Anthony Giddens' structuration theory (1986) as the grand theory. This theory explains the dialectical relationship between structure and agency—where social structures such as rules, institutions, and technologies not only constrain, but are also shaped and reproduced by human actions. In this context, AI technology, village institutions, and modern value systems are positioned as part of the structure, while the Osing people, with their customary practices, local ecological knowledge, and mutual cooperation system, are understood as active agency. The relationship between the two is not hierarchical, but rather mutually shaping. When local communities adapt AI according to their local wisdom—for example, by integrating natural signs such as insect sounds and wind direction into the water prediction system—they are actually reconstructing the technological structure within their own social framework. Thus, structure and agency are not poles apart, but are in a constant process of reproduction and transformation through everyday social practices.

To deepen the conceptual dimension of the process, this structuration theory was complemented with some more contextualized middle-range theories. First, Chambers and Conway's Sustainable Livelihoods Approach (SLA) Chambers and Conway (1992) was used to map the strengths and vulnerabilities of the community based on five key assets: natural, human, social, physical and financial capital. SLA helps to see that the adaptability of the Osing community is strongly supported by the strength of social and cultural capital, although constrained by infrastructure and funding aspects. In the structuration framework, these assets are not static, but rather developed and negotiated through institutional practices and technological innovation.

Second, Miranda Fricker's (2007) theory of epistemic justice expands the understanding of community resistance to AI as a form of epistemic injustice—that is, when local knowledge is marginalized by modern algorithmic logic that claims universal truths. The epistemic tensions that arise in the process of technological intervention reflect that technological decision-making cannot be separated from the context of local knowledge values and legitimacy. Furthermore, co-production of knowledge theory is used to explain the importance of establishing a dialog between science and society in technology development(Jasanoff, 2004). AI, in this context, should not be understood as a neutral system that comes from outside, but should be built in a participatory manner with the community, so that it emerges as a culturally meaningful social system. The concepts of community-based AI (Crawford, 2021) and participatory AI emphasize that technology can be a collaborative tool if it is designed by involving local actors as co-designers, not just passive users.

In this framework, the development of AI that is able to read local natural signs or facilitate community decision-making becomes a form of social innovation born from the synthesis of structure and agency. By combining structuration theory as a broad framework and SLA, epistemic justice, and co-production as intermediate theories, this research builds an analytical foundation that enables the integration of technology into social systems and community livelihoods in an inclusive and adaptive manner. This framework not only explains how communities respond to external pressures, but also how they actively reshape these structures through adaptation strategies, cognitive resistance, and institutional transformation. Therefore, the integration of AI in water conservation cannot be understood simply as the application of technology, but rather as a meaningful social process, where community agency becomes a major force in articulating equitable, locally rooted, and sustainable development.

RESEARCH METHODS

Research Approach

This study adopts a reflective qualitative approach with embedded semi-quantitative analysis to explore the socio-ecological, institutional, and epistemic dynamics of AI-based water conservation in indigenous communities. The approach allows for a critical examination of the interaction between community agency, technological systems, and institutional structures, while maintaining awareness of the researchers' positionality throughout the data collection and analysis process. This reflective qualitative approach emphasizes researcher positionality and community voice (Finlay, 2002), while allowing for an embedded semi-quantitative analysis of socio-ecological patterns (Creswell and Plano Clark, 2018). This combination enables a dialogical understanding of technology integration within cultural and institutional contexts (Reason and Bradbury, 2008).

Research Setting: Socio-Ecological Context of the Osing Villages

The research was conducted in four Osing villages located in Banyuwangi Regency, East Java: **Olehsari, Kemiren, Paspan, and Kenjo**. The selection of these villages was purposive, based on their ecological significance as upstream buffer zones of the Ijen Mountains conservation area, their diversity of socio-institutional arrangements, and varying levels of exposure to water crisis risks. **Olehsari** represents communities with strong traditional ecological knowledge and emerging digital adaptation. **Kemiren** reflects a community with well-preserved cultural institutions but moderate financial capacity. **Paspan** presents agricultural dependence with limited water access and financial vulnerability. **Kenjo** illustrates emerging ecotourism-based diversification but with significant social and institutional gaps. This multi-site design allows for a comparative understanding of how different livelihood structures influence community readiness for technology adoption.

Fieldwork and Data Collection

Multiple qualitative methods were employed to obtain a comprehensive and triangulated dataset:

- **In-depth interviews** with community leaders, farmers, youth representatives, and village officials to explore perceptions of AI, local knowledge systems, and water management practices.
- **Focus Group Discussions (FGDs)** involving village stakeholders to capture collective decision-making dynamics, technological resistance, and institutional coordination.
- **Participatory observations** to document water conservation practices, social interaction patterns, and traditional ecological indicators.
- **Document analysis** including village regulations, water resource maps, institutional records, and conservation program reports.

All interviews and discussions were conducted in the local language (Osing and Bahasa Indonesia) and transcribed for subsequent thematic analysis.

3.4 Semi-Quantitative Scoring and Visual Analysis

To operationalize the **Sustainable Livelihoods Approach (SLA)**, qualitative findings were translated into semi-quantitative scores using a 5-point Likert scale, ranging from 1 (very weak) to 5 (very strong).

The scoring criteria for each livelihood capital were determined through:

- Triangulation of data sources (interviews, FGDs, observations, documents).
- Consensus discussions among the research team.
- Contextual reflection on socio-cultural conditions of each village.

The semi-quantitative scores were then used to develop:

- **Radar charts** to visualize inter-village comparisons of SLA capitals.
- **Heatmaps** to map spatial vulnerability to water scarcity.
- **SWOT diagrams** to assess village-specific readiness for AI integration.

This embedded scoring approach allows qualitative richness while providing structured visual representation of inter-village differences in adaptive capacity and institutional readiness.

3.5 Data Analysis Procedure

The analysis followed a **thematic coding process**, grounded in the theoretical frameworks of:

- **Structuration Theory** (Giddens) — to capture the dialectical relationship between structure (technology, institutions) and agency (community adaptation).
- **Epistemic Justice** (Fricker) — to address knowledge marginalization and epistemic resistance toward AI intervention.
- **Knowledge Co-Production** (Jasanoff) — to conceptualize participatory AI development involving indigenous actors.

Themes were inductively generated from field data while being continuously interpreted in dialogue with the theoretical frameworks to ensure both empirical grounding and conceptual rigor.

Validity and Ethical Considerations

To ensure the rigor and credibility of this qualitative inquiry, several strategies were employed to strengthen data validity. Methodological and source triangulation was applied by integrating various data collection techniques and comparing insights across multiple informants and field sites (Lincoln and Guba, 1985; Patton, 2015). Member-checking was conducted with key informants to validate the interpretation of data and ensure that the researchers' analytical reflections resonated with participants' lived realities (Creswell and Poth, 2018). Additionally, peer-debriefing sessions within the research team served to critically examine emerging findings and minimize subjective bias during the analytical process (Tracy, 2010).

In terms of ethical research conduct, the study adhered to a protocol rooted in respect, inclusivity, and cultural sensitivity. Informed consent was obtained from all participants prior to any data collection, with clear communication about the study's aims and the voluntary nature of participation. Confidentiality was maintained throughout, including the anonymization of identities in both field notes and publications. Importantly, all research interactions were carried out with deep cultural respect, recognizing the Osing community's traditional knowledge systems not as subordinate, but as epistemologically equal to formal scientific frameworks (Smith, 2012). This commitment to ethical integrity not only protected participant rights but also upheld the principle of epistemic justice in indigenous research settings.

RESULTS AND DISCUSSION

Research results

1. Natural Assets and Regional Topography

One important aspect in assessing ecosystem resilience to water crises is the **topographic characteristics of the region**. In the context of this research, Olehsari Village and its neighboring villages (Kemiren, Paspan, and Kenjo) have a unique geographical position as a buffer zone of the Ijen Mountains. To clarify the physical conditions of the region, the following illustrative topographic map is presented:

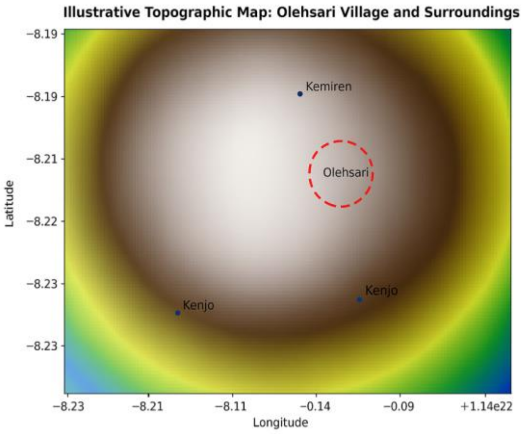

Figure 1: Topographic Map of Olehsari Village and Ijen Mountains Buffer Area

This map shows the **elevation contours and gradations of** Glagah Sub-district, where Olehsari Village is located in the **transition zone between highlands and agricultural settlements**. This position makes Olehsari Village a **strategic upstream area** in the local hydrological system. Major springs such as *Sumber Kedaton* originate from this area and flow to downstream villages such as Paspan and Kenjo.

Spatial Vulnerability to Water Crisis

In terms of vulnerability, villages on lower contours such as **Paspan and Kenjo** tend to experience water deficits during the dry season. The results of water discharge monitoring show that the **decrease in discharge from 1.87 L/sec to 0.98 L/sec** during the August-October 2024 period greatly impacts villages in the downstream zone. The sloping contour structure from northwest (Kemiren, Olehsari) to southeast (Kenjo, Paspan) not only indicates the direction of water flow, but is also an **indicator of potential pressure on the sustainability of water resources**. Decreased buffer vegetation and land conversion in higher areas can directly impact downstream through decreased discharge, sedimentation and drought.

Implications for AI Intervention Design

These topographical dynamics reinforce the argument that technologies such as **predictive AI** should be developed contextually:

- Upstream villages such as Olehsari can be the location of **early warning systems** for rainfall prediction and discharge measurement.
- Downstream villages such as Paspan can receive a **water distribution dashboard** system that is integrated with the prediction results from upstream villages.
- Topography also determines the distribution of digital sensors and network coverage if Internet of Things (IoT)-based AI is implemented.

2. Social and institutional assets: The Foundation of Community Strength

Social assets have the highest score (3.5), indicating the strength of the community in the practice of gotong royong, village deliberation and close relationships between residents. This social capital becomes a major force in supporting innovations when directed in a participatory manner. Social and institutional capital play a crucial role in determining the success of water conservation at the community level. In Olehsari Village and its surroundings, a relatively active and interacting institutional structure was found through village deliberation forums, water farmer groups (poktan), and the central role of traditional leaders.

The village government is the main coordination node, interacting directly with water farmer groups, Osing traditional leaders, youth organizations, and technical agencies (such as the Agriculture Office and PUPR Office). These interactions are not only administrative, but also ideological-in terms of how local values are brought into water resources management. The following figure illustrates the relationship map between actors involved in the community-based water management system in Olehsari Village:

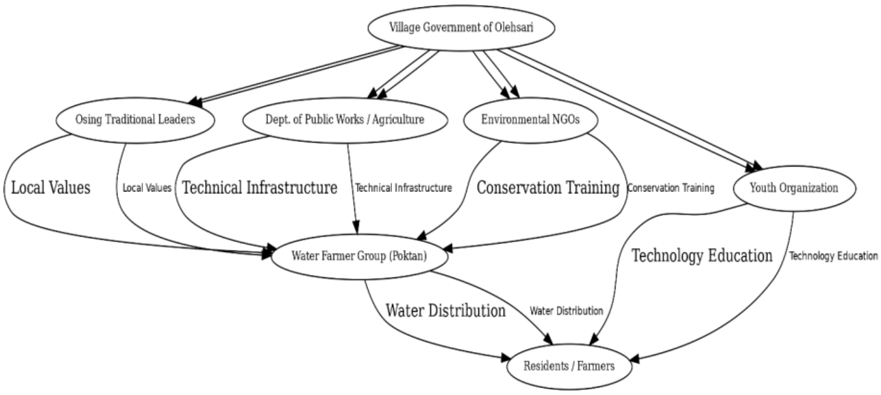

Figure 2. Institutional Map of Water Management in Olehsari Village

The institutional map of water management in Olehsari Village shows the structure of relationships between actors that play a role in ensuring the sustainability of community-based water distribution. The Olehsari Village Government is at the center as the main coordinator, establishing formal connections with various local and external stakeholders. They interact directly with Osing traditional leaders who play an important role in maintaining local values, as well as linking cultural heritage with conservation practices through customary legitimacy and ecological symbols . In addition, the village government also works closely with the Department of Public

Works and the Department of Agriculture who provide technical support and basic infrastructure such as irrigation channels and water storage systems. The institution also involves environmental NGOs that have a role in providing conservation training, especially in terms of applying environmentally friendly methods and participatory approaches. On the other hand, Karang Taruna as a youth organization is responsible for the technology education aspect, introducing the use of water sensors, weather prediction applications, and digital monitoring systems that are easily accessible to residents. The entire flow of support converges on the Water Farmer Group (Poktan), which is the main executor in distributing water to residents and farmers. Poktan functions as a technical node that carries out institutional decisions as well as a link between the formal system and field needs.

At the end of this institutional chain are citizens and farmers, as the end users of the water distribution system. Their role is not passive, as the success of conservation is largely determined by engagement, maintenance of shared infrastructure, and adaptation to innovation. Through this map, it can be concluded that water management in Olehsari Village does not only depend on technological support or infrastructure, but on social coherence between actors, the functioning of local institutions, and collaboration between traditional knowledge and modern approaches. This institutional approach is an important foundation in designing a sustainable and community-based water conservation system.

Transformation Structure and Institutional Roles

In the SLA perspective, the transformation process includes not only infrastructure and formal rules, but also inter-actor interactions and power logics that influence access to livelihood assets. Village governments in the four study sites play an important role as a link between the technocratic logic of development and local values. Customary institutions, such as the Rembug Belik in Kemiren or the Water Farmers Group in Olehsari, are the managing actors that instill social legitimacy to conservation programs. However, there is still unequal access to external assistance and regulations that are not yet responsive to local dynamics. Therefore, technology-based conservation policies should be designed through an institutional transformation approach that allows: (1) recognition of the role of customary institutions in the decision-making process, (2) utilization of formal village structures as implementers of technology adaptation, and (3) establishment of a collaborative ecosystem between local and external actors. Only then will the transition process towards AI-based water conservation systems be sustainable, non-marginalizing, and responsive to community needs. The structural transformation referred to in the SLA emphasizes that it is not enough to build infrastructure or introduce technology; there needs to be changes in access, participation, and decision-making processes (DFID, 1999; Scoones, 1998)." Findings on the active role of local institutions in negotiating technology demonstrate the hallmarks of *adaptive governance*, namely the importance of resource management systems that are flexible, learn from local experiences, and are able to accommodate social and ecological dynamics (Folke et al., 2005) .

Human Assets: Local Knowledge vs Digital Literacy

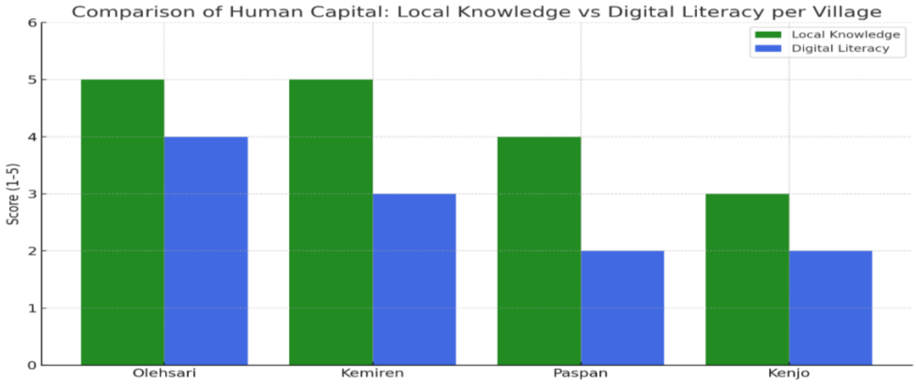

Figure 3: Comparison Chart of Local Knowledge and Digital Literacy per Village

The graph above illustrates the comparison between two dimensions of human capital, namely local knowledge and digital literacy, in four villages: Olehsari, Kemiren, Paspan and Kenjo. The graph shows that local knowledge tends to be higher than digital literacy in all observed villages. Olehsari and Kemiren villages scored the highest for local knowledge at 5, indicating strong cultural heritage, local wisdom and traditional practices that are still preserved and applied in people's daily lives. On the other hand, Paspan and Kenjo villages recorded lower scores in this aspect, at 4 and 3 respectively, indicating the depletion of intergenerational knowledge transfer or the diminishing of local cultural practices. In terms of digital literacy, there is a notable gap. Olehsari tops the list with a score of 4, indicating the relatively good level of digital readiness of its community compared to other villages. Kemiren follows with a score of 3, while Paspan and Kenjo lag behind with a score of 2 each. This reflects the challenges in access, utilization and mastery of digital technology, particularly in the more remote villages or those lacking supporting infrastructure. The gap between local knowledge and digital literacy suggests that while cultural heritage is still strong, technology utilization has not been fully adopted equally.

These findings suggest the need for a holistic and contextual approach to human development. On the one hand, strengthening digital literacy should be a priority to encourage innovation and connectivity, especially in Paspan and Kenjo. On the other hand, in villages such as Olehsari and Kemiren, policies that integrate local wisdom with the utilization of digital technology will be more effective in creating adaptive and sustainable development. Therefore, future human resource development strategies need to emphasize the synergy between cultural preservation and digital transformation, so that villages are not only technologically literate, but also firmly rooted in their local identity.

Simply put, a comparison between local knowledge and digital literacy in four villages - Olehsari, Kemiren, Paspan and Kenjo - shows that villagers are generally still stronger in terms of traditional knowledge than digital technology capabilities. In Olehsari and Kemiren villages, for example, people still practice a lot of local wisdom such as mutual cooperation in water management, knowledge about seasons, and traditional farming methods. This is their strength in protecting the environment and building social solidarity. However, despite their cultural strengths, their ability to use digital technology is still limited. The use of technology is usually limited to communication through cellphones, such as using WhatsApp. Meanwhile, in Paspan and Kenjo, the challenges are more severe. Local knowledge is starting to fade because not many people are passing on traditions from their parents. On the other hand, technological skills are also low. Many residents are not accustomed to using digital devices, and access to training and the internet is still very limited. This leaves them behind both in terms of preserving local heritage and in utilizing technology for daily life.

This finding shows that human resource development in villages cannot only focus on technology. The local wisdom that still exists must be preserved and can be used as an entry point to introduce technology. For example, digital training can start from simple things such as how to market local agricultural products online, or manage irrigation with simple applications. This approach will be more easily accepted by the community as it is close to their daily lives. In other words, the development strategy must be balanced: not abandoning traditional values, but also not closing itself off from progress. If the two can be combined, then villages will be better prepared to face the challenges ahead - remaining firmly rooted in culture, while being open to the changing times.

Natural Assets: Dependency and Vulnerability

The score for natural assets is 2.5, indicating community dependence on one main water source and minimal backup systems. The risk of drought and environmental degradation is increasing due to climate change and land degradation. Observations of water discharge were conducted manually by a local water farmer group with the help of simple measuring instruments (2-inch pipe, measuring bucket, and stopwatch), during the period August-October 2024 at Sumber Rejeki spring. The purpose of the observation was to detect patterns of decreasing water discharge during the dry season.

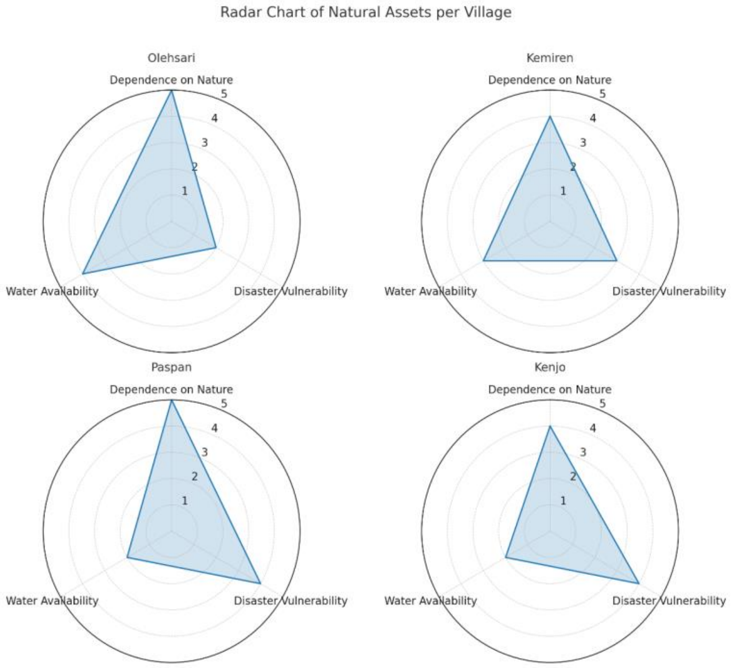

Figure 4. Radar Chart of Natural Capital of Each Village

This radar chart illustrates that: **Olehsari** village is the most ecologically prepared, with a combination of high dependency but low vulnerability and sufficient water. **Kemiren** village has balanced conditions but still needs strengthening in risk management. **Paspan and Kenjo** villages have the highest vulnerability and limited access to water, making them priorities for conservation and disaster risk management interventions.

Physical Assets: Limited Supporting Infrastructure

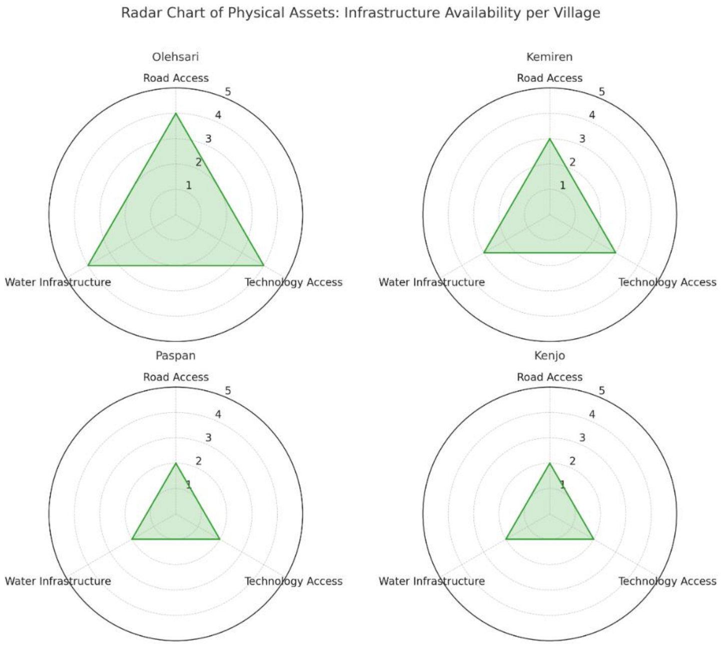

Figure 5. Radar Chart of Availability of Physical Assets for Each Village

The following radar chart illustrates **Physical Assets** based on the **availability of supporting infrastructure** in four villages: Olehsari, Kemiren, Paspan, and Kenjo. The three main indicators used are: **Road Access, Technology Access and Water Infrastructure. Olehsari village** has the highest score in all aspects (score 4), indicating that the physical infrastructure in this village is relatively good and supports economic activities and basic community services.

Kemiren village shows a medium score (score of 3 across all indicators), meaning that infrastructure conditions are adequate but there is still room for improvement. **Paspan and Kenjo** villages have the lowest scores (score 2 across all indicators), indicating serious limitations in road infrastructure, technology and clean water. These conditions have the potential to slow economic progress and hinder access to basic services.

7. Financial Assets and Community Readiness for Water Conservation

Financial assets are one of the key components in the *Sustainable Livelihoods Approach* (SLA) framework that determine a community's ability to **fund, maintain and develop water management infrastructure**, including in the context of technology integration such as artificial intelligence (AI). To measure the financial strength of each village, four key indicators were assessed: **access to credit, allocation of village funds for conservation, presence of external assistance, and level of community self-help**.

The assessment results are visualized in the following radar chart:

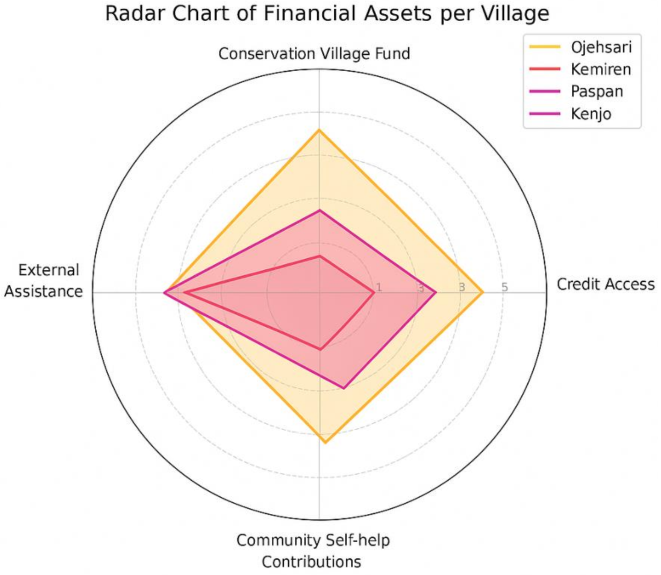

Figure 6. Radar Chart of Financial Assets and Conservation Funding Capacity by Village

1. **Olehsari Village** showed the most balanced and financially strong performance, scoring high on all indicators. The access to farmer cooperatives, the allocation of a special village fund for conservation (IDR 25 million/year), and community contributions through farmer group dues make this village **relatively self-sufficient in terms of water conservation financing**. This makes Olehsari a strong candidate for piloting the integration of AI-based conservation technologies.
2. **Kemiren** is in an intermediate position with potential for self-help and customary institutions, but limited access to structured conservation financing. The village fund does not specifically allocate a conservation budget, and access to credit is only available in the form of customary cooperatives that are still limited in scale.
3. **Paspan** experiences the most serious challenges with the lowest scores on aspects of self-help and village funds. The high reliance on external assistance indicates long-term structural vulnerability. The absence of local financing institutions or active conservation programs makes it **difficult for** the village **to become a technology test site without intensive mentoring support**.
4. **Kenjo** is in a vulnerable position, mainly due to a combination of dependence on external sources and the absence of adequate village fund allocations. Despite the spirit of self-help, these efforts have not been well organized institutionally.

This radar chart confirms that the **approach to technology-based interventions cannot be uniform**. Villages with high financial strength such as Olehsari can be targeted as *model villages*, while villages with limited capacity such as Paspan need to **focus on strengthening their financial and institutional foundations first**, before moving into the AI-based technology adoption stage.

8. Regional Vulnerability to Water Crisis

To gain a comprehensive picture of ecological risk and water access resilience at the village level, a vulnerability assessment was conducted based on five key indicators: **access to clean water, dependence on a single water source, dry season stress, quality of water infrastructure, and external program support**.

The assessment was conducted semi-quantitatively through triangulation of interview results, field observations and analysis of village documents. The vulnerability scale was determined between **1 (low)** and **5 (very high)**. The results of the mapping were visualized through the following heatmap:

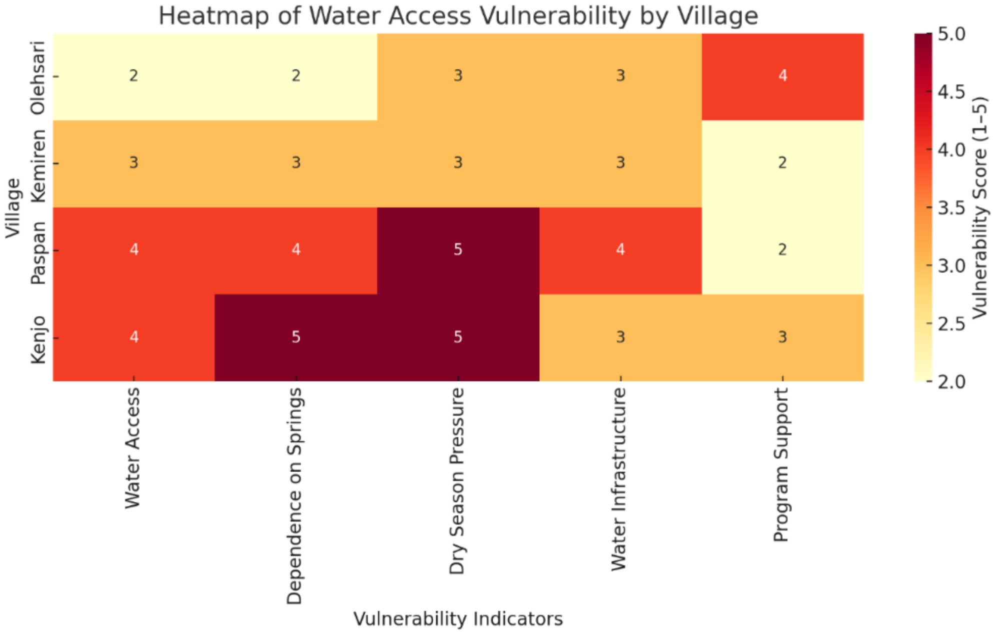

Figure 7. Heatmap of Regional Vulnerability to Water Crisis by Village

Based on the heatmap above, it can be seen that **Paspan and Kenjo Villages** have the highest vulnerability scores, particularly in the aspects of **dependence on one spring and dry season stress**. This has implications for the high risk of crop failure, water distribution disruption and the need for emergency backup systems. In contrast, **Olehsari Village** has a lower vulnerability score, as it is supported by access to the main spring (*Sumber Kedaton*) and there is basic infrastructure and conservation programs already in place partly through community groups. **This heatmap helps identify priority areas** for AI-based water conservation technology interventions, with a tiered approach according to the level of vulnerability and institutional readiness.

9. Community Readiness to Adopt AI Technology

To understand the readiness of village communities to accept and adapt Artificial Intelligence (AI) technology in water conservation, a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis was conducted on four study villages: **Olehsari, Kemiren, Paspan, and Kenjo**. This analysis was conducted based on the results of in-depth interviews, participatory observations, and focus group discussions (FGDs).

The following graph presents a visualization of each village's SWOT score on a scale of 1-5 for each dimension:

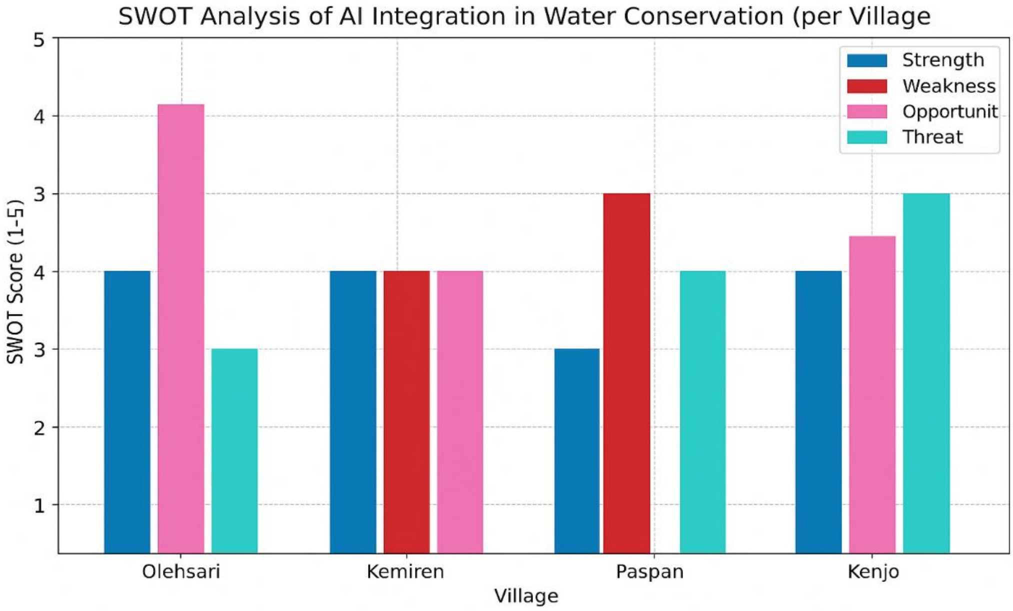

Figure 8. SWOT Chart of Community Readiness to Adopt AI Technology by Village

a. **Olehsari Village** shows a major strength (Strength = 4) in the form of active institutional networks and structured local knowledge. Opportunity = 5 is also high due to support from village youth and village government for digital innovation.
b. **Kemiren Village** has strong historical and cultural values, but faces internal challenges in the form of cultural resistance to external interventions (Weakness = 3). Nonetheless, the potential for collaboration remains open.
c. **Paspan Village** is in a weak position (Strength = 2, Weakness = 4) due to weak infrastructure and lack of community participation in the water management forum. However, there are opportunities for external parties to provide community-based mentoring and training.
d. **Kenjo Village** faces relatively high threats (Threat = 4) from land conversion and natural tourism pressure. Although village institutions are still functioning, technology-based interventions need to be combined with strengthening local spatial and regulatory arrangements.

This SWOT analysis shows that **participatory approaches cannot be generic**. A context-based intervention design is required:

a. **Olehsari** can be used as a model village for pilot projects.
b. **Kemiren and Kenjo** require a cultural approach and dialog between values.
c. **Paspan** requires technical and institutional capacity strengthening before AI implementation can be effective.

Epistemic Tensions and Resistance to AI

The application of smart technologies such as Artificial Intelligence (AI) in water conservation not only raises technical challenges, but also **epistemological challenges**. In this context, epistemology refers to the **source, structure and legitimacy of knowledge**. When AI is introduced as a data-driven prediction and decision-making tool, there are **points of friction with local knowledge systems based on experience, spiritual values and ecological intuition**.

A. Knowledge Conflict: Science vs Locality

In Olehsari and Kemiren villages, some people showed **skepticism and even resistance** to new technologies that were considered "foreign", "unfriendly to local values", or "not answering the context of their lives". This tension is evident in informants' narratives such as:

"If everything is determined by tools, then where is the role of those of us who have been protecting the springs since our ancestors?" - Mrs. T, traditional leader of Olehsari Village

When AI technology is built in a participatory manner, as suggested in the concept of *community-based AI*, the structure itself is transformed. From the perspective of *Actor-Network Theory*, AI is not a neutral entity, but an actor in a network that reshapes social practices and community decisions. Sensors, weather predictions, even cell phones become part of a ***socio-technical assemblage*** that needs to be understood symmetrically with humans (Latour, 2005) .

B. Epistemic Justice: Bridging Knowledge

The concept of **epistemic justice** is key. Technology brought from outside the community must **recognize and integrate local knowledge**, not replace it. In this research, the form of epistemic justice is realized through:

a. Involvement of indigenous leaders in the AI prediction system design process
b. Integration of local cues (insect sounds, wind direction, soil moisture) into the sensor data system
c. Workshop forum to harmonize language between technocrats and communities

C. Generational Differences in Acceptance

Epistemic tensions also have a **generational dimension**. Young people such as youth organizations and millennial farmers in Olehsari are more open to AI, as long as the **interface is simple and directly useful**:

"If we can see the rain prediction through our cell phones, it will be very helpful. But the display should not be complicated." - Rian, Olehsari Village youth

Meanwhile, older generations prioritize spiritual and relational knowledge systems with nature. Both are valid and important, but need a **platform for dialog so as not to negate each other.**

D. Knowledge Hybrid Model: Community-Based AI

From the field results, the potential for **knowledge hybridization** was found, i.e. **the incorporation of AI as a technical tool** rather than the sole determinant. This creates a space for collaboration between "technological sense" and "local wisdom". Resistance can also transform into **collaboration**, if the process is conducted in a sensitive, participatory and transparent manner.

> *"If everything is determined by tools, then where is the role of those of us who have been protecting the springs since our ancestors?"* - Mrs. T, traditional leader of Sanenrejo Village
>
> *"We are not anti-technology. What we expect is to be involved from the start. Don't just come with tools and leave."* - Mbah Widi, traditional elder of Paspan Village

Instead, some youth and village officials proposed collaborative models, such as a predictive irrigation dashboard integrated with local needs.

> *"If we can know when it rains and can organize the water turn, farmers will not continue to lose money."*
> - Rizal, farmer youth of Kemiren Village.

Hybrid models that combine AI as a technical tool with local ecological intuition create new possibilities for participatory and culturally relevant conservation systems. Field results indicate the potential for ***hybrid knowledge***, where algorithmic logic does not replace local knowledge, but blends to form a contextualized prediction system. This is in line with Turnbull's(2000) idea that knowledge is effective in social systems when it results from dialog across epistemologies**.**

11. Comparative Analysis of SLA Capital Readiness between Villages

The radar chart visualization of the five *Sustainable Livelihoods Approach* (SLA) capitals shows the variation in readiness between villages in supporting the integration of community and technology-based water conservation. The five capitals consist of: **natural, human, social, physical, and financial capital**, each of which plays an important role in determining the resilience and adaptability of villages to climate change and technological innovations such as AI.

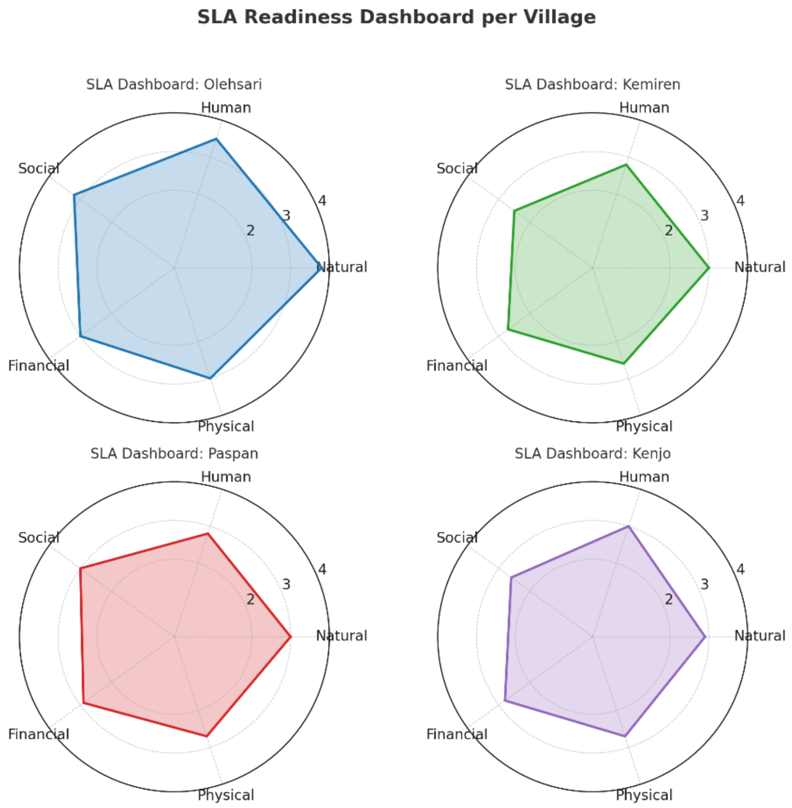

Figure 9. Comparative Radar Chart of Five SLA Capitals per Village

The **Sustainable Livelihood Approach (SLA)** was employed to assess the sustainability readiness of four villages: Olehsari, Kemiren, Paspan, and Kenjo. This assessment refers to five key dimensions: **Natural Capital, Human Capital, Social Capital, Financial Capital,** and **Physical Capital**. The analysis reveals the variation in readiness and resilience of each village in supporting sustainable economic development based on the strengthening of local assets.

A. Olehsari Village: The Highest Level of Readiness

Olehsari demonstrates the highest level of sustainability readiness. Nearly all dimensions scored above 3.5. **Natural Capital** is the village's primary strength, reflecting the availability and quality of natural resources that can support agriculture and local economic development. **Human Capital** is also high, indicating good human capacity in terms of education, health, and adaptive community skills. In addition, **Social Capital** is strong, showing good social cohesion, mutual trust, and supportive social networks. Both **Financial Capital** and **Physical Capital** are relatively stable, although there is still room for improvement, particularly in expanding access to productive financial services.

Overall, Olehsari has a solid foundation for sustainable development. With adequate social capital, natural resources, and human capacity, future policy interventions can focus on strengthening local institutional capacities, fostering micro-enterprise innovation, and optimizing local resource utilization sustainably.

B. Kemiren Village: Emerging Potential with Structural Challenges

Kemiren shows a moderate level of readiness, with all dimensions scoring between 2.8 and 3.0. Both **Natural Capital** and **Human Capital** are relatively stable, but slightly lower than Olehsari. Attention is particularly needed in **Financial Capital** and **Physical Capital**, which reflect limited access to productive financing, household income strengthening, and underdeveloped supporting infrastructure.

In this context, Kemiren holds significant growth potential if interventions target strengthening local economic institutions, improving financial literacy, and providing better basic infrastructure. Strengthening community social networks will also reinforce **Social Capital** as a foundation for social and economic resilience.

C. Paspan Village: Balanced Stability Across Dimensions

Paspan exhibits a fairly balanced readiness profile across all dimensions, with scores ranging from 3.0 to 3.3. **Social Capital** is slightly stronger than that of Kemiren, indicating solid social cohesion, active community participation, and relatively strong inter-community cooperation networks.

This balanced condition offers excellent opportunities for community-driven development approaches, while continuing to enhance productive community capacities, diversify local economic activities, and optimize supporting infrastructure.

D. Kenjo Village: The Need to Strengthen Social and Human Capital

Kenjo presents the most vulnerable readiness profile among the four villages. Scores across all dimensions tend to cluster around 3.0. **Social Capital** is the weakest dimension compared to other villages, highlighting the need for interventions to strengthen social solidarity, community participation, and the development of local social institutions.

Human Capital also requires further enhancement, including improving productive skills, education, and community health. Strengthening Kenjo's human and social capital will significantly improve its resilience in facing development dynamics. Priority interventions should include capacity-building programs, productive group empowerment, and facilitation of local institutional strengthening.

The four villages demonstrate varied levels of readiness, offering insight into each village's specific intervention needs. **Olehsari** is ready to advance into locally driven innovation-based development, **Paspan** and **Kemiren** require financial and institutional reinforcement, while **Kenjo** demands fundamental investment in social and human capital. These findings can serve as a basis for developing **SLA Readiness-based development programs**, allowing for more accurate targeting of each village's needs, potentials, and weaknesses.

The radar diagram used in this study illustrates the readiness level of five types of livelihood assets within the Sustainable Livelihoods Approach (SLA) framework for community-based water conservation and AI technology integration. This conceptual model illustrates the linkages between the village community's livelihood system and opportunities for AI technology integration in water conservation. At the base of the model, five types of livelihood assets identified through the Sustainable Livelihoods Approach (SLA) become the main foundation of the community's adaptation system. These five assets include: natural assets (such as water springs and productive land), physical assets (reservoirs, irrigation channels, and supporting equipment), social assets (mutual cooperation, local institutions), human assets (local knowledge, skills, and education), and financial assets (savings, business capital, or village assistance). These assets are the main parameters in determining a community's capacity to deal with the threat of a water crisis.

On top of this asset layer, there are social dynamics that influence how communities respond to technological innovations, especially AI. There are two poles of response: first, resistance from some community groups, especially indigenous peoples, who see AI as a form of foreign intervention that ignores local values and community ecological rhythms; and second, the emergence of a spirit of innovation from young people and village officials who see AI as an opportunity to improve efficiency, predictive accuracy, and data-driven decision-making. These tensions form an epistemic transition space where local knowledge and digital technologies interact, negotiate, and-in some cases-conflict.

The highest layer of this model is the representation of community-based AI as a form of transformation. In this context, AI is not positioned as a technocratic solution that comes from outside, but rather as a system that is collaboratively designed by the community itself, taking into account local languages, cropping habits, seasonal rhythms, and social values. With active community participation and alignment with the local social-ecological context, AI can serve as a tool that strengthens livelihood and water conservation strategies, rather than replacing them. Overall, this model emphasizes the importance of an integrative and participatory approach in the development of water conservation technologies. The use of AI should be placed within a social framework that respects the diversity of local knowledge, cultural values, and livelihood systems. Thus, the transformation of water conservation systems will be more sustainable, equitable, and able to address structural challenges at the community level.

12 Livelihood Strategies and Technology Adaptation

Within the SLA framework, livelihood strategies are a form of community adaptation to a combination of environmental pressures, asset access and institutional dynamics. The research findings show that Osing communities do not only rely on traditional agricultural practices for livelihoods, but also develop diversified strategies such as conservation-based ecotourism (in Kenjo), NGO collaboration (in Olehsari), and integration of water resource-based micro-enterprises (such as local bottled water in Kemiren). These strategies reflect the community's efforts to adapt to climate change pressures and economic opportunities, although they are still limited by their asset capacity.

The adoption of AI technologies, if designed in a participatory manner, can strengthen these strategies by providing predictive information, efficient distribution systems, and community-based data access. However, if community livelihood strategies are not part of the AI system design, the technology risks social dislocation or unsustainable dependence on external systems.

13. Expected Livelihood Outcomes

Based on the SLA approach, all water conservation and AI technology integration efforts are expected to not only result in technical changes, but also bring about positive transformations to **community livelihood outcomes**. Findings in the four Osing villages show that the community desires a more **stable**, **equitable** and **sustainable** water management system, both in terms of distribution and quality. On the economic side, income generation through business diversification (such as water ecotourism, local bottled water production and precision agriculture) is an important goal. On the social side, communities expect improved **institutional coherence** and recognition of customary roles in resource governance. Another expectation is reduced **dependence on external assistance** through strengthened self-help capacity and community financing.

In general, the **livelihood outcomes expected** by the community include: (1) reduction in the risk of drought and water crisis through AI-based predictive systems, (2) strengthening the capacity of communities to make decisions based on data and local wisdom, and (3) development of conservation systems that are not only efficient, but also socially just and culturally recognized. These expectations become an important foundation for the design of technology that is not only adaptive to the ecosystem, but also responsive to community values and aspirations.

Discussion: Integration of SLA Framework, AI, and Community Livelihood Transformation

Anthony Giddens' structuration theory approach provides a useful framework for understanding how technology, institutions and social practices in water conservation dynamically influence each other. Giddens (1986) states that social structure consists of rules and resources that not only constrain social action, but also facilitate it-a concept called the *duality of structure*. In the context of this research, structure is manifested in the form of technological systems (AI), village regulations, government conservation programs, as well as modernizing development values. On the other hand, the Osing people, with their ecological knowledge and customary institutions, act as agents that reproduce and transform these structures through their daily practices and collective decisions. For example, the introduction of an AI-based prediction system into Olehsari village's water management was not immediately adopted. Some residents showed skepticism because the technology brought a new logic that was different from the traditional way of reading the season or water discharge. However, instead of a total rejection, there was a process of adaptation, where the village youth group began to integrate data from AI with local natural signs. This shows how structure (in the form of technology) is not deterministic, but actively negotiated by the community (agency) to create a new, more contextualized system. This reinforces Giddens' argument that structure and agency do not stand in opposition, but are intertwined in a cycle of social reproduction. Through Giddens' structuration approach, the dynamic between AI and local knowledge is reflected as a reciprocal process of social reproduction. In this framework, the Osing community is positioned as an active actor who reconstructs the social structure, not just a passive recipient of external technological intervention.

Furthermore, community-based water management in Osing villages shows the existence of locale-social *spaces* where structure and agency meet concretely. Village meetings, water farmer groups (Poktan), and customary institutions such as *Rembug Belik* are arenas where residents, village government, and external actors (NGOs or technology providers) interact. It is in these spaces that decisions about conservation, water sharing, and acceptance of AI technologies are determined not only by structural forces (e.g. regulations or technical tools), but also by long-standing social values, norms, and beliefs within the community. In this framework, changes that occur in the community are not merely the result of technological intervention, but are the result of a process of social *reflexivity*. The Osing community is not only an object of technological change, but an active subject that evaluates, selects, and modifies structural elements that come from outside. For example, when the AI is not able to capture local indicators such as bird sounds or morning fog patterns that are commonly used by residents as seasonal markers, the technology will be criticized and adjusted. This process shows that modernization is not a linear process determined by external forces, but is formed from the reciprocal interaction between mutually constructing structure and agency.

When AI technology is built in a participatory manner, as suggested in the concept of *community-based AI*, the structure itself is transformed. AI is no longer an instrument of technocratic domination, but becomes part of a new social system, where community values and local logics shape the way the technology is designed and operated. In other words, the success of AI integration in water conservation lies not only in the sophistication of the technology, but in the extent to which the system is able to fit within the existing social structure and enable sustainable reconstruction of the structure through community action. Therefore, structuration theory provides an important understanding that innovations in technology-based water conservation cannot be separated from social dynamics. Institutional structures, customary values, belief systems and the practice of gotong royong are not barriers to change, but elements that shape the arena of social transformation. In this context, the Osing people do not merely adapt to change, but play an active role in shaping it - an ongoing process of structuration, where technology and tradition negotiate with each other in response to sustainability challenges.

Within the framework of the Sustainable Livelihoods Approach (SLA), the sustainability of community livelihoods is strongly influenced by five types of assets: natural, human, social, physical and financial capital (Chambers and Conway, 1992; Scoones, 1998) This study found that Osing communities in Olehsari, Kemiren, Kenjo and Paspan Villages have a very distinctive and unbalanced asset structure. Their strength lies in social and natural capital, while physical and financial capital are relatively weak. This imbalance is a determining factor in the community's readiness to deal with ecological pressures, climate change, and technological integration such as AI.

Adaptation Assets and Inequalities Strong social capital-such as customary institutions, gotong royong, and local legitimacy-is an important foundation for building community-based water conservation systems. However, limitations in physical capital such as digital infrastructure and water distribution systems, as well as financial capital such as access to conservation financing and village funds, limit the scale and speed of innovation adoption. This inter-capital imbalance creates very different readiness profiles between villages, as shown by the radar chart in this study.

Livelihood Strategies and Adaptive Diversification The livelihood **strategies** of the Osing community show forms of diversification that are responsive to change. In Kenjo, there is development of conservation ecotourism. In Olehsari, collaboration with NGOs and utilization of local institutions strengthen conservation. In Kemiren, water source-based micro-enterprises, such as local bottled water production, have emerged. This reflects community adaptive capacity driven by a combination of social and human capital. However, these strategies still rely heavily on local capacity and are not yet optimally supported by adequate funding systems and digital infrastructure. The adoption of AI technologies, if designed in a participatory and local asset-based manner, can strengthen these strategies through rainfall prediction systems, efficient water distribution management, and community-based data visualization. However, without integration with community livelihood strategies, technology risks creating social dislocation or dependency on external systems.

Institutional Transformation and the Role of Local Actors In the SLA perspective, the transformation process includes inter-actor interactions, power relations, and access to assets. The village government plays a strategic role as a link between technocratic logic and local values. Customary institutions such as Rembug Belik and Kelompok Tani Air play a role as knowledge managers and guardians of social legitimacy. However, there are still regulatory gaps and unequal access to external support. Therefore, conservation policies should be designed through inclusive institutional transformation-recognizing local authority, activating formal village structures, and building collaboration between internal and external actors.

Vulnerability **Context and Technology Risks** The vulnerability heatmap shows that villages like Paspan and Kenjo face high stress due to dependence on a single water source, inadequate infrastructure and weak financial capacity. When technology is introduced without social and institutional readiness, these villages risk digital and epistemic exclusion. In this context, the SLA helps map not only assets, but also points of vulnerability that need to be watched out for in any intervention.

Epistemic Justice and Knowledge Tensions The integration of AI into water conservation systems in indigenous communities has epistemological implications. Local knowledge based on spirituality, ecological experience, and symbolic relationships with nature is often marginalized by technocratic knowledge systems based on data and algorithms. Epistemic tensions arise when AI is positioned as an objective and universal solution, while local communities have a more contextual and participatory framework (Fricker, 2007; Milan and Treré, 2019) . This phenomenon can be categorized as a form of *epistemic injustice*, which is injustice in the recognition and distribution of knowledge. When technological systems do not recognize the validity of local knowledge, communities not only lose their role in decision-making, but also experience cultural delegitimization. In the framework of *political ecology*, inequality in access to technology and the dominance of technocratic narratives over local knowledge reflect power relations that shape who is recognized as an 'expert' and who is marginalized in environmental decision-making processes (Blaikie and Brookfield, 1987) . In this context, a co-production of knowledge (Jasanoff, 2004) approach is crucial, designing AI as an open system that can learn from natural signs, ecological intuitions, and collective community practices. Recognition of this epistemic tension also suggests that resistance to AI is not simply a technical or cultural obstacle, but a form of protection for the cognitive autonomy of communities. Therefore, any AI system design must include deliberative spaces that are equal, inclusive, and based on local values-so that technology does not become an instrument of domination, but a means of collaboration between ways of knowing. In line with post-development critique (Escobar, 1995), the resistance to AI that emerges in the Osing community reflects a form of rejection of the hegemony of modern technology as the only narrative of progress. Local knowledge is not just an alternative, but an equal form of epistemology in constructing the future.

Expected Livelihood Outcomes The ultimate goal of community-based water conservation and AI integration is the achievement of sustainable livelihood outcomes: equitable water security, increased self-help capacity, increased income through local economic diversification, and recognition of customary institutions and values as key elements of governance. With the SLA-based approach, livelihood outcomes are not only assessed by technical or economic indicators, but also by the social legitimacy and cultural acceptability of the developed system.

Affirmation of SLA's Role as a Critical Framework SLA is not just a social-ecological diagnostic tool, but also a critical framework for designing equitable and contextualized technological interventions. It enables a holistic mapping of strengths, weaknesses, opportunities and challenges, and offers direction for the design of community-based technologies that are not only efficient, but also socially inclusive and culturally meaningful. Therefore, an integrative approach between SLA, AI and epistemic justice principles is a key strategy in building resilient, collaborative and sustainable water conservation systems. The following figure presents an integrative framework between SLA, AI and the principles of epistemic justice that serves as the conceptual basis for building resilient and inclusive community-based water conservation systems:

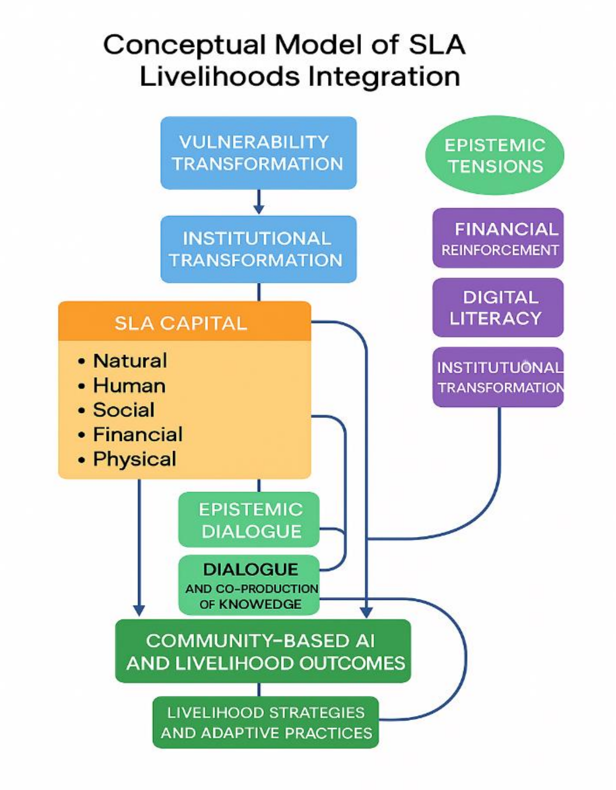

Figure 10 Conceptual Model of AI and Livelihoods Integration in Community-based Water Conservation System

This figure This conceptual model illustrates an integrative approach to sustainable livelihood development through the **Sustainable Livelihoods Approach (SLA)** combined with the utilization of **community-based artificial intelligence (AI)**. The goal is to foster adaptive and context-specific livelihood strategies through institutional transformation, capacity building, and epistemic dialogue among involved actors. The transformation begins with **vulnerability transformation**, which addresses various economic, social, and environmental shocks. This stage then leads to **institutional transformation**, involving changes in the structure and functioning of local and regional institutions to become more responsive to community needs and sustainability challenges.

Institutional transformation contributes to the development of **SLA capitals**, comprising five key categories: **natural, human, social, financial, and physical capital**. These capitals represent essential assets that communities possess or can access to support their livelihoods. The model emphasizes the importance of **epistemic dialogue**, a process of knowledge exchange between local communities, academics, policymakers, and other actors. This enables **co-production of knowledge**, which is not merely technocratic but participatory and contextually grounded.

The outcome of this process is the implementation of **Community-Based AI and Livelihood Outcomes**, referring to AI technologies that are designed, developed, and implemented through active community participation. Rather than top-down solutions, these technologies serve to enhance **livelihood strategies and adaptive practices** that align with local realities.

The model also includes additional reinforcing elements:

1. **Financial reinforcement**, which enhances access to financial resources;
2. **Digital literacy**, which strengthens communities' ability to utilize information technologies;
3. **Continued institutional transformation**, recognizing this as an ongoing process.

However, in practice, this integration is not without challenges. The model acknowledges the emergence of **epistemic tensions**, particularly when local, contextual knowledge comes into conflict with modern technoscientific paradigms. These tensions must be mediated through inclusive and ethnographic dialogue mechanisms to prevent the dominance of a single knowledge system. Overall, the model underscores that the success of AI-based sustainable livelihoods depends heavily on dialogical processes, recognition of diverse community assets, and adaptive institutional designs. This approach not only bridges technology and community but also redefines how technology can function as a tool of social empowerment, rather than merely one of efficiency.

CONCLUSION

This research shows that the integration of artificial intelligence (AI) technology in community-based water conservation in the Osing indigenous region can only be successful if it is done within a framework that respects the diversity of community livelihood assets, local institutional structures, and community-lived knowledge systems. The Sustainable Livelihoods Approach (SLA) has proven to be effective in holistically mapping asset conditions and identifying strength and vulnerability points of each village. The findings show that the community's main strengths lie in social and natural capital, while physical and financial capital are the main barriers to technology adoption. This imbalance creates the need for differentiated intervention strategies tailored to the village profile. At the same time, the epistemic tension between local and algorithmic logic is a critical challenge that must be bridged through deliberative, participatory and co-productive mechanisms. The success of technology-enabled water conservation is not only determined by the sophistication of the system, but by the extent to which it is able to ethically interact with community values. AIs that are developed collaboratively, sensitive to local culture, and connected to the community's real-life livelihood strategies are much more likely to be accepted and utilized sustainably. Thus, SLA serves not only as a social-ecological analysis tool, but also as an ethical and political framework in designing equitable technological transformation. The integration of AI, SLA and epistemic justice is the most relevant approach in building resilient, inclusive and meaningful water conservation systems in the context of indigenous peoples such as the Osing community.

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