Indigenous Knowledge Systems (IKS) and Artificial Intelligence for Climate Change in Zimbabwen

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Abstract

Climate change presents a global challenge that demands innovative, inclusive, and context-sensitive responses. A significant research gap exists regarding the systematic, ethical, and effective integration of IKS into AI systems, particularly in rural African contexts. This study explores the integration of Indigenous Knowledge Systems (IKS) with AI as a culturally embedded approach to climate change adaptation and mitigation. Employing a qualitative research design, including semi-structured interviews, direct observation, and content analysis, this research draws on sociometric theory to examine community social structures and identify key custodians of Indigenous knowledge. These insights inform the development of context-aware AI models capable of incorporating traditional knowledge into climate solutions. Triangulation of qualitative data ensured depth and cultural relevance in assessing the approach's effectiveness. Findings reveal that integrating IKS into AI strengthens local applicability and acceptance of climate interventions while fostering the preservation and recognition of traditional knowledge. The study offers insights with implications for policy, sustainable development, and inclusive innovation, particularly in regions vulnerable to climate change. This research highlights the importance of leveraging diverse knowledge systems to co-create resilient, community-driven responses to environmental challenges.

Keywords: Sociometric Theory, Climate Change, Artificial Intelligence, Indigenous Knowledge Systems

Introduction

Climate change remains one of the most urgent global challenges, with profound impacts on ecosystems, economies, and human communities [Malhi et al., 2020]. In Zimbabwe, its effects are increasingly evident through erratic rainfall patterns, prolonged droughts, and frequent extreme weather events. Rural areas such as Chivi District are particularly vulnerable due to their dependence on rain-fed agriculture and natural resources for livelihoods. In such contexts, innovative, locally grounded solutions are essential to strengthen community resilience and adaptive capacity. Indigenous Knowledge Systems (IKS) have garnered increasing recognition as crucial components in climate change adaptation strategies [Gaza and Masere, 2025]. These systems consist of long-standing traditions, practices, and belief structures developed through continuous interaction with local ecosystems [Berkes, 2018]. In Zimbabwe, where adaptive capacity remains limited and rural populations face increasing climate-related stressors, the integration of IKS with advanced technologies such as Artificial Intelligence (AI) presents a promising pathway for addressing environmental challenges. According to projections by the Intergovernmental Panel on Climate Change [IPCC, 2021], Zimbabwe is likely to experience rising temperatures, declining rainfall, and more frequent extreme weather events. These climatic shifts pose significant threats to food security and agricultural productivity, particularly in vulnerable regions such as Chivi District, where subsistence farming underpins the local economy. As such, the integration of traditional knowledge with cutting-edge technology is increasingly viewed as a strategy to enhance resilience and sustainability. IKS have proved to offer locally relevant, sustainable approaches to managing natural resources, predicting weather patterns, and guiding agricultural practices. When combined with the predictive and analytical capabilities of AI, which can process large datasets and generate climate models, these traditional systems can be reinforced and revitalised [Reed et al., 2019]. The convergence of IKS and AI thus holds significant potential for improving climate preparedness and informed decision-making, especially in resource-constrained rural settings.

Background and Research

Chivi District in Masvingo Province, Zimbabwe, is experiencing severe impacts from climate change, including erratic rainfall patterns, prolonged droughts, and extreme weather events that jeopardise the livelihoods of its predominantly agricultural communities [Magwegwe et al., 2024: 126]. Traditional farming practices, which have sustained these communities for generations, are increasingly inadequate in addressing these emerging environmental challenges. With limited literature, there is consequently an urgent need for innovative approaches that integrate Indigenous Knowledge Systems (IKS) with modern technologies, particularly Artificial Intelligence (AI), to enhance community resilience and safeguard food security under changing climatic conditions. Despite the potential benefits of such integration, the methods and frameworks for effectively combining these distinct knowledge systems remain insufficiently explored. Critical questions persist regarding the contextual relevance, cultural sensitivity, and practical feasibility of implementing hybrid IKS-AI approaches in rural Zimbabwean settings.

The integration of Indigenous Knowledge Systems (IKS) and Artificial Intelligence (AI) offers both opportunities and challenges that warrant careful exploration. This study is therefore guided by the following research questions: How can Indigenous Knowledge Systems be effectively integrated with Artificial Intelligence to enhance climate change resilience in Chivi District? What social dynamics and power structures influence the transmission and adoption of Indigenous Knowledge within the community? How can AI algorithms be designed to incorporate Indigenous Knowledge in a manner that is culturally sensitive and contextually relevant? and What are the anticipated benefits and potential challenges associated with the integration of IKS and AI in addressing the impacts of climate change?

Recent Initiatives

Recent initiatives demonstrate the promising potential of integrating Indigenous Knowledge Systems (IKS) with Artificial Intelligence (AI) to enhance climate resilience. The Climate Change Adaptation and Resilience project in Kenya combines traditional ecological knowledge with AI technologies to promote climate-smart agricultural practices. This initiative has successfully supported thousands of farmers by leveraging AI-driven, locally tailored weather forecasts and agricultural advice aligned with Indigenous practices [O'Neill et al., 2021]. The Indigenous Climate Change Assessment in Canada also applied AI to systematically document and analyse IKS, ensuring Indigenous perspectives are incorporated into climate change discourse and policymaking processes. Indigenous Knowledge Systems offer a rich, context-specific, and holistic approach to environmental management, with a strong emphasis on community engagement and participatory decision-making. These systems provide low-cost, adaptive solutions but face challenges in scalability due to reliance on oral transmission, which risks knowledge erosion over time [Sillitoe, 2002]. Conversely, AI excels in scalability and large-scale data processing, enabling more precise climate modelling and resource optimisation. However, adopting AI in resource-constrained contexts is complicated by issues such as data bias, limited contextual relevance, and high implementation costs. The convergence of IKS and AI thus presents a compelling avenue to bolster climate resilience, particularly in vulnerable communities such as those in Chivi District, Masvingo Province, Zimbabwe. Therefore, by synthesising the strengths of traditional knowledge and cutting-edge technology, this hybrid approach offers sustainable, equitable, and culturally appropriate solutions that empower communities to participate actively in climate adaptation efforts.

Indigenous Knowledge Systems (IKS)

Vogel and Bullock [2021] emphasise the critical role of integrating Indigenous Knowledge Systems (IKS) with scientific approaches to enhance climate resilience. Their study in Canada highlights how Indigenous communities hold unique and valuable insights into local ecosystems and sustainable practices. The authors advocate for collaborative frameworks that honour Indigenous rights and knowledge, ensuring AI tools are developed in partnership with these communities to maximise cultural relevance and effectiveness. Similarly, Gomes and Guerra [2023] examine case studies from the USA where the integration of IKS into climate adaptation strategies has yielded culturally relevant and effective climate action plans. They call for policy reforms that recognise IKS as a vital component of climate science and for increased funding to support projects merging AI with traditional knowledge. Ayoola et al. [2024] explore how AI can support the documentation and dissemination of Indigenous knowledge on biodiversity conservation in the USA. They recommend developing accessible, AI-powered platforms that empower Indigenous communities to share knowledge widely while retaining control over its use.

IKS represent a vital resource for communities in Zimbabwe's Chivi District, contributing significantly to climate change adaptation and food security. These knowledge systems have evolved through sustained interactions between people and their environment, forming rich, context-specific, and culturally embedded understandings [Berkes, 2018]. Their deep-rooted connection to local ecosystems allows communities to address environmental challenges with a nuanced understanding often absent in conventional scientific approaches, which may overlook these critical contextual insights [Belle et al.]. IKS embody a holistic environmental management approach, integrating social, spiritual, and ecological dimensions [Nakashima et al., 2019]. Traditional agricultural practices, for example, frequently involve rituals and communal gatherings that strengthen social cohesion while promoting sustainable resource use, thereby enhancing resilience amid climate variability [Gadgil et al., 2003].

A key strength of IKS lies in its emphasis on community participation. Local communities are central to decision-making, fostering ownership of environmental stewardship [Mercer et al.]. This inclusive approach increases the likelihood of successful climate adaptation strategies as interventions align with community values and knowledge. Furthermore, IKS often present low-cost, locally appropriate solutions, especially important in resource-constrained settings by leveraging accessible materials and practices without requiring expensive technologies [Thornton et al.]. Their adaptive nature, shaped by continuous evolution, allows traditional practices to respond flexibly to changing environmental conditions [Berkes et al.]. Indigenous communities worldwide have demonstrated this adaptability by modifying agricultural methods to cope with shifting weather patterns.

Nonetheless, Indigenous Knowledge Systems face significant challenges. Their scalability is limited, as practices effective in one locality often do not easily transfer to different geographic or cultural settings [Gondo et al.]. Furthermore, the oral transmission of much Indigenous knowledge complicates efforts to preserve and disseminate it across generations and regions, increasing the risk of loss and cultural erosion [Grey et al.].

AI Algorithms

Artificial Intelligence algorithms bring distinct advantages and constraints to climate change mitigation. AI has proved to be capable of rapid, large-scale data analysis, enabling the detection of patterns and trends not readily discernible through traditional methods, enhancing climate understanding and informing policy and interventions [Hawkins et al.]. Predictive modelling is another critical benefit of using AI models. AI models have proved capable of forecasting climate-related events such as extreme weather by analysing historical data and key indicators, facilitating proactive risk management [Fischer et al.]. AI models have also proved to optimise resource management through automation. A good example is AI-driven irrigation systems that adjust water use based on weather predictions, thereby promoting efficiency and sustainability [Zhou et al.]. Its ability to integrate diverse data sources further enriches climate models, providing comprehensive, multi-dimensional views of environmental scenarios [Teng et al.].

However, AI implementation faces challenges, including data bias, contextual limitations, and significant costs, which may exacerbate inequalities in resource-poor environments [Obermeyer et al.]. For AI to be effective and equitable, it must be designed with cultural sensitivity and respect for Indigenous knowledge.

Comparison of IKS and AI Algorithms

Indigenous Knowledge Systems (IKS) and Artificial Intelligence (AI) offer complementary strengths while facing distinct challenges. IKS are highly valued for their contextual relevance, holistic approach to environmental management, and strong emphasis on community engagement—factors crucial for tackling complex climate issues. In contrast, AI's strengths lie in its scalability, advanced data analytics, and predictive capabilities. The low-cost, adaptive nature of IKS stands in contrast to AI's often high implementation costs and susceptibility to bias [Fischer et al.]. While IKS struggles with limited scalability and dependence on oral transmission, which hinders wider application, AI's technical capacities enable broader reach but require careful adaptation to local contexts to avoid mismatches.

Hybrid Approach

Integrating Indigenous Knowledge Systems (IKS) and AI presents a promising hybrid model to enhance climate resilience. One key strategy involves incorporating IKS into AI algorithms, as embedding traditional knowledge improves contextual accuracy and cultural relevance. Additionally, AI can be used to document and preserve IKS by digitising oral traditions, enabling broader intergenerational knowledge transfer. Developing community-based AI initiatives is another vital approach; co-creating AI solutions with local communities ensures relevance, ownership, and effective climate adaptation. Furthermore, integrating traditional knowledge into climate modelling allows AI-enhanced models to provide nuanced, accurate predictions that inform decision-making. This hybrid approach leverages the strengths of both IKS and AI, fostering sustainable, equitable, and culturally grounded climate solutions. It empowers vulnerable communities to actively shape their adaptation strategies while bridging traditional and modern knowledge systems.

The literature revealed significant potential in merging Indigenous Knowledge Systems with Artificial Intelligence to bolster climate resilience. This synergistic integration respects cultural traditions while harnessing technological advances, promoting sustainable practices and community empowerment. Therefore, by combining these forms of knowledge, vulnerable communities can better navigate the challenges of climate change and contribute to shaping resilient futures.

Methodology

This research employed a qualitative approach combined with an extensive literature review to comprehensively investigate the integration of Indigenous Knowledge Systems (IKS) with Artificial Intelligence (AI) for enhancing climate change resilience in Chivi District, Zimbabwe. The use of qualitative methods allowed the study to capture the complex community dynamics and the multifaceted nature of IKS.

In-depth interviews were carried out with 50 key informants, including local leaders, elders, traditional knowledge holders, and agricultural experts. These interviews gathered rich, detailed insights into individual experiences with climate adaptation strategies and the role of IKS. Focus group discussions brought community members together to explore their perspectives on climate change, the value of IKS, and the potential integration of AI technologies. This participatory approach enriched the data and encouraged community engagement and ownership of the research process.

Sociometric analysis played a crucial role in identifying key IKS knowledge holders and mapping social networks within the community. Sociometric techniques visualised relationships among community members, revealing influential individuals who possessed critical traditional knowledge. This analysis deepened understanding of how knowledge was transmitted and utilised within the community, highlighting the social structures supporting IKS.

A literature review identified AI algorithms suitable for climate resilience applications. Collaboration with local stakeholders took place through co-design workshops, where AI tools incorporating IKS were developed. These workshops facilitated knowledge exchange between technologists and community members, ensuring AI algorithms were culturally sensitive and contextually appropriate. This collaborative process empowered local stakeholders by involving them directly in technological development, thereby enhancing the likelihood of successful adoption and implementation.

Findings and Discussion

The integration of Indigenous Knowledge Systems (IKS) with Artificial Intelligence (AI) offers a distinctive opportunity to enhance climate resilience in Chivi District, Zimbabwe. Drawing on interviews, observations, and literature review, this study identified key traditional practices with potential for synergy with modern technology.

Flocking Birds as Weather Indicators

Local communities have long used the behaviour of flocking birds as a natural indicator to predict weather patterns. Machine learning models, such as Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks, can analyse large datasets combining historical bird migration patterns with recorded weather data. These models identify complex patterns and trends that may not be obvious through observation alone. In order to capture bird flock movements, technologies such as satellite imagery, GPS tracking devices, drones, acoustic sensors, and camera trap networks can be employed to collect spatial and temporal data on bird activity. This data, when combined with environmental variables such as rainfall, temperature, and humidity, allows AI models to learn how specific bird behaviours correlate with weather conditions over time. As a result, the AI can generate timely and accurate alerts about upcoming weather events. This integration enhances the traditional method by providing farmers with actionable, data-driven forecasts that support better decision-making for planting and harvesting.

Algorithm	Application
1. Recurrent Neural Networks (RNNs)	Suitable for time-series data, RNNs can identify trends in bird migration patterns over time, predicting future movements in relation to weather.
2. Long Short-Term Memory Networks (LSTMs)	Capturing long-term dependencies, LSTMs can analyze how historical weather patterns influence bird migration, providing insights for future conditions.
3. Support Vector Machines (SVM)	SVMs classify migration patterns based on environmental variables, predicting a typical behaviors associated with specific weather conditions.
4. Random Forests	This ensemble method analyzes diverse features related to the environment and bird behavior, improving accuracy in forecasting weather events.
5. Gradient Boosting Machines (GBM)	Effective for regression tasks, GBMs can predict weather metrics like temperature and rainfall based on historical bird migration data.

Table 1: Algorithms for Analyzing Flocking Birds

These machine learning models can enhance the predictive capabilities of traditional bird observation methods, empowering local farmers with actionable insights for effective agricultural planning.

Brewing of Traditional Beer

The brewing of traditional beer remains a vital cultural and spiritual practice, often linked to rainmaking rituals and ancestral appeasement during drought. Traditionally, elders selected optimal brewing times by observing environmental cues such as temperature, humidity, and the lunar cycle. AI models could augment this practice by analysing historical brewing events in relation to climate data. Algorithms such as Decision Trees, Multivariate Regression, Neural Networks, and Time Series Analysis were employed to determine the optimal climatic conditions for successful brewing. These models used inputs such as brewing dates, fermentation success rates, and environmental parameters, with data sourced from ethnographic interviews, weather stations, IoT sensors measuring temperature and humidity, and historical calendars. The integration of AI into this practice ensures cultural preservation while promoting climate-aligned timing that enhances both ritual efficacy and agricultural resilience.

Algorithm	Application
Decision Trees	Create models evaluating factors impacting brewing conditions, such as temperature and humidity, to determine optimal brewing times.
Time Series Analysis	Techniques like ARIMA can analyze historical brewing data alongside climate trends to forecast the best times for brewing.
Multivariate Regression Analysis	This method helps understand relationships between fermentation time, ingredient quality, and climate conditions, optimizing brewing processes.
Neural Networks	Feedforward neural networks can predict successful brewing outcomes by capturing complex relationships between brewing data and climate variables.
Reinforcement Learning	This algorithm optimizes brewing practices by simulating conditions and learning which methods yield the best results.
K-Means Clustering	An unsupervised learning algorithm to group historical brewing data into clusters based on similar conditions, helping identify optimal practices.

Table 2: Algorithms for Brewing Traditional Beer

Integrating these algorithms into the brewing process enhances the resilience and sustainability of traditional practices, ensuring cultural significance while adapting to changing climatic conditions.

Water Management Techniques

Water management techniques, particularly rainwater harvesting, are vital in the Chivi District, where communities face inconsistent rainfall and frequent droughts. Traditionally, local farmers relied on indigenous knowledge, such as observing soil dryness, plant stress, or cloud movement, to decide when and how to collect and use rainwater. While these practices have supported survival for generations, their accuracy and timing can be improved through the application of Artificial Intelligence (AI). AI predictive algorithm models, such as Random Forest Regression, Support Vector Machines (SVM), and Long Short-Term Memory (LSTM) networks, can be trained using historical rainfall data, soil moisture levels, evapotranspiration rates, and topographical features. These models draw on data collected through IoT soil sensors, satellite imagery, weather stations, and local climate records. By analysing these variables, the models forecast rainfall trends, predict drought onset, and determine optimal irrigation schedules. This integration allows farmers to make data-driven decisions on water usage, ensuring that stored rainwater is used efficiently and sustainably. It also enhances traditional knowledge systems by combining them with scientific precision, thereby improving agricultural resilience and food security in the face of climate change.

Algorithm	Application
1. Random Forest Regression	Predict soil moisture levels based on environmental factors like rainfall and temperature, providing robust insights for irrigation scheduling.
2. Support Vector Regression (SVR)	Model the relationship between soil moisture and climatic inputs, capturing non-linear relationships to predict water availability.
3. Artificial Neural Networks (ANN)	Train on historical rainfall and soil moisture data to predict future moisture levels, optimizing irrigation practices.
4. Time Series Forecasting	Models such as ARIMA can analyze historical rainfall data to forecast future precipitation patterns, aiding irrigation adjustments.
5. K-Means Clustering	Categorize weather patterns and corresponding soil moisture levels to tailor irrigation strategies to specific scenarios.
6. Genetic Algorithms	Optimize irrigation schedules by simulating various strategies based on predictive models of rainfall and soil moisture
7. Reinforcement Learning	Facilitate real-time decision-making for irrigation by simulating strategies and learning which methods are most effective under changing conditions.

Table 3: Algorithms for Water Management

These algorithms enable farmers in Chivi District to develop a comprehensive water management system that conserves water and optimizes irrigation practices, ultimately improving agricultural resilience.

Observation of Seasonal Patterns of Plants

The rich indigenous knowledge of plants and their seasonal patterns presents a valuable opportunity for AI integration. Local communities often share detailed oral narratives and stories about plant behaviours, flowering times, and harvesting periods, which are traditionally passed down through generations. Natural Language Processing (NLP) models can analyse these narratives collected via interviews, focus groups, or community archives to extract key information about seasonal patterns and plant-related practices. By converting unstructured oral knowledge into structured digital data, these models help create comprehensive databases that preserve traditional wisdom and support climate-adaptive agricultural planning.

Algorithm	Application
1. Latent Dirichlet Allocation (LDA)	Identify themes within local narratives about plants, uncovering prevalent seasonal patterns and associated practices.
2. Named Entity Recognition (NER)	Extract specific plant names and seasonal cues from narratives, creating structured data that reflects local knowledge.
3. Sentiment Analysis	Gauge community attitudes toward certain plants and practices, providing insights into cultural significance and changes due to climate variability.
4. Word Embeddings	Create vector representations of words to analyze relationships between plants and seasonal behaviors, identifying relevance to specific conditions.
5. Clustering Algorithms	Group similar narratives based on plant characteristics and seasonal patterns, identifying common practices across communities.
6. Sequence-to-Sequence Models	Generate summaries or interpretations of seasonal patterns, distilling complex information into accessible formats for farmers.
7. Reinforcement Learning	Optimize decision-making related to planting and harvesting based on seasonal patterns through simulated scenarios.

Table 5: Algorithms for Traditional Weather Forecasting

Adopting these algorithms can enhance traditional weather forecasting methods, making them more accurate and relevant to local conditions. This integration of AI with Indigenous Knowledge Systems (IKS) not only preserves cultural practices but also equips farmers with the necessary tools to adapt to changing climatic conditions, ultimately improving agricultural resilience and food security.

By leveraging Indigenous Knowledge Systems through AI algorithms, the Chivi District can empower local communities, fostering a holistic approach to climate adaptation that respects and preserves their cultural heritage while addressing contemporary challenges.

Integrating Indigenous Knowledge Systems (IKS) with Artificial Intelligence (AI) offers significant benefits for agriculture and community resilience. This fusion improves decision-making by combining traditional insights with advanced predictive analytics, enabling farmers to adapt effectively to climate change and improve crop yields. It also supports cultural preservation by documenting and respecting traditional practices within modern technological frameworks. AI enhances climate resilience through detailed local environmental analysis, aiding communities in understanding and responding to climatic shifts vital for food security. Tailoring solutions to local contexts ensures their relevance, while interdisciplinary collaboration encourages respect and innovation between indigenous knowledge holders and scientific experts.

Conclusion

This study explores the integration of Indigenous Knowledge Systems (IKS) with AI as a culturally embedded approach to climate change adaptation and mitigation. Based on its findings, community engagement must remain central to enhancing the integration of Indigenous Knowledge Systems (IKS) with Artificial Intelligence (AI), ensuring that local voices and traditional knowledge are respected and included in AI development. Firstly, capacity-building initiatives should empower community members through training programmes focused on data collection and analysis, promoting ownership and sustainability of these practices. Secondly, the establishment of open data platforms will facilitate the sharing of observations and findings, enriching datasets for AI models and encouraging collaboration across regions. Furthermore, interdisciplinary research partnerships offer opportunities to combine diverse perspectives and drive innovation. Moreover, pilot projects that merge IKS and AI across different agricultural contexts can act as effective models for broader implementation. In addition, continuous monitoring and evaluation frameworks are crucial for refining approaches and measuring their impact. Finally, advocacy for supportive policies that recognize and promote the integration of IKS and AI will improve access to resources and funding. This strategic collaboration enhances agricultural resilience and productivity while preserving cultural heritage for future generations.

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