

Indigenous Knowledge Systems and Modern Meteorology in Short-Term Weather Forecasting in Rural Zimbabwe: Implications for Climate Adaptation Policy

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Abstract

Indigenous Knowledge Systems (IKS) constitute a vital yet undervalued resource in weather forecasting, particularly in rural communities across sub-Saharan Africa where formal meteorological services remain inaccessible or unreliable. This study investigated the role and effectiveness of IKS in weather forecasting in Ward 13, Zvishavane District, Zimbabwe, using a qualitatively dominant mixed-methods case study design underpinned by Actor-Network Theory. Data were collected from 70 participants, comprising 60 households, five community leaders, three Non-Governmental Organisation representatives, one ward councillor and one representative from the Meteorological Services Department, through structured questionnaires, semi-structured interviews, and direct observations. Six principal IKS indicator categories were documented, that is, plant phenology (utilised by 95% of respondents), animal behaviour (by 72%), celestial indicators (by 55%), wind direction (by 40%), cloud formations, and soil and insect activity. Respondent perceptions indicate that IKS demonstrated higher accuracy than modern meteorological methods for short-term forecasts, achieving 60% and 65% accuracy for daily and weekly predictions respectively. Modern

methods proved higher for monthly (60%), seasonal (55%), and hazard (65%) forecasts. Oral tradition was identified as a declining preservation mechanism (91% disagreement rate), whereas formal educational integration received unanimous endorsement (100%) as the preferred preservation and transmission approach. Five key integration challenges were identified, language barriers, divergent epistemological paradigms, limited documentation, scaling and resolution disparities, and insufficient institutional support. A tiered IKS–Meteorological Integration Model is proposed to leverage the complementary strengths of both systems across forecast time-horizons. These findings carry significant implications for climate adaptation policy, rural food security, and the co-production of meteorological knowledge in Zimbabwe and comparable African contexts.

Keywords: Indigenous Knowledge Systems; weather forecasting; rural Zimbabwe; climate adaptation policy; Actor-Network Theory; integration model

I. INTRODUCTION

For millennia, indigenous and rural communities across Africa have developed sophisticated, ecologically grounded knowledge systems to interpret atmospheric conditions, anticipate seasonal shifts, and manage climate-related risks long before the advent of modern meteorological technology (Mafongoya, 2018; Balehegn et al., 2019). These Indigenous Knowledge Systems (IKS), encompassing observations of plant phenology, animal behaviour, celestial patterns, wind direction, and soil conditions, have been documented across pastoral and agrarian communities in East Africa, Southern Africa, and beyond, demonstrating functional utility in guiding agricultural planning, livestock management, and disaster preparedness (Balehegn et al., 2019; Zachary et al., 2021; Irumva et al., 2021). Despite growing international recognition of IKS within climate adaptation frameworks, including its formal incorporation into IPCC assessment reports, this accumulated body of forecasting knowledge remains systematically undervalued, poorly documented, and largely excluded from formal meteorological practice (IPCC, 2022; Leal Filho et al., 2022; Gwenzi et al., 2016).

IKS is defined as the cumulative body of knowledge, practices, and beliefs developed by communities through sustained interaction with their local environments across generations (Mapara, 2009; IPCC, 2022). This definitional framing is significant, as it positions IKS not as folklore or anecdote, but as a structured, place-based epistemology that operates alongside conventional scientific methods. Yet formal meteorological infrastructure across sub-Saharan Africa remains sparse, underfunded, and largely inaccessible to smallholder farmers, precisely the communities most dependent on accurate weather information for food security and livelihood decisions (Leal Filho et al., 2022; Donkor et al., 2019). This institutional gap creates both the necessity and the opportunity for IKS to serve as a practical, low-cost forecasting resource.

Across Africa, the functional breadth of IKS has been documented in diverse ecological and cultural settings. In north-eastern Ethiopia, Balehegn et al. (2019) found that pastoralists employ a rich repertoire of biological and atmospheric indicators for weather prediction, with direct implications for livestock and rangeland management. In western Kenya, the Nganyi community has accumulated sophisticated rainfall

prediction knowledge anchored in bio-physical and astronomical indicators (Zachary et al., 2021), while Rwanda's IVUBIRO system integrates cloud morphology, flora, fauna, and wind patterns for seasonal forecasting (Irumva et al., 2021). In Zambia, Mbewe et al. (2019) documented comparable IKS practices in Mukonchi Chiefdom, reinforcing the cross-national relevance of locally embedded forecasting systems. Despite this growing body of evidence, empirical studies that systematically compare IKS accuracy against modern meteorological methods across multiple forecast time-horizons remain scarce, particularly within the Zimbabwean context (Gwenzi et al., 2016; Zvobgo et al., 2022).

Zimbabwe is acutely exposed to climate-related hazards including recurrent droughts, floods, and tropical cyclones, yet rural communities frequently lack reliable access to scientific weather forecasts (Mavhura, 2020). Existing studies from Chimanimani (Chundu & Sithole, 2020), Chiredzi (Zvobgo et al., 2022), and Bikita (Mafongoya, 2018) confirm that IKS remain in active use for local forecasting, while being simultaneously threatened by intergenerational knowledge loss, climate-induced indicator shift, and institutional marginalisation. Gwenzi et al. (2016) further documented that over 80% of smallholder farmers across multiple Zimbabwean districts rely on IKS indicators despite the availability of scientific forecasts, underscoring both the depth of community trust in IKS and the persistent gap between formal meteorological services and rural end-users.

This article addresses a specific empirical gap, a systematic, quantitative comparison of IKS and modern meteorological forecast accuracy across multiple time-horizons in a rural Zimbabwean setting. The four objectives of this study are (i) to document the key IKS indicators employed locally; (ii) to compare IKS and modern forecast accuracy at daily, weekly, monthly, seasonal, and hazard scales; (iii) to examine socio-cultural factors influencing IKS preservation; and (iv) to identify challenges to IKS–modern integration. The study culminates in a Tiered IKS–Meteorological Integration Model with direct implications for climate adaptation policy in Zimbabwe and the broader sub-Saharan African context.

II. LITERATURE REVIEW

Indigenous Knowledge Systems are increasingly recognised in international climate science as a legitimate epistemological resource for weather forecasting and climate adaptation. The IPCC Sixth Assessment Report formally acknowledges IKS as a source of locally relevant, empirically grounded knowledge that can complement scientific approaches in understanding climate variability and informing adaptive responses (IPCC, 2022). Leal Filho et al. (2022) similarly affirm that IKS constitutes a valuable yet systematically underutilised asset in Africa's climate adaptation architecture, arguing that its continued marginalisation from formal policy frameworks represents a missed opportunity for building community resilience. This growing recognition reflects a broader epistemological shift in climate science, away from the exclusive primacy of quantitative modelling towards pluralistic, co-produced knowledge frameworks that acknowledge the validity of place-based environmental observation accumulated over generations (Apraku et al., 2021).

Understanding how IKS operates within weather forecasting networks requires a theoretical framework capable of bridging the human, ecological, and institutional dimensions of knowledge production. This study applies Actor-Network Theory (ANT), originally developed by Bruno Latour and colleagues (Latour, 1987), which examines how heterogeneous actors (both human and non-human), interact to shape how knowledge is produced, validated, and used. ANT is particularly well suited to IKS research because it resists the hierarchical separation of scientific and indigenous knowledge, instead treating both as products of dynamic networks of actors, that is, community elders, biological indicator species, ecological environments, local institutions, meteorological agencies, and policymakers (Apraku et al., 2021). Within the rural Zimbabwean context, ANT illuminates how power asymmetries between scientific and indigenous epistemologies shape both forecasting effectiveness and integration outcomes (Mapara, 2009; Gwenzi et al., 2016). Crucially, ANT's emphasis on network design rather than knowledge replacement provides the theoretical foundation for the Tiered Integration Model proposed in this study (Joshua et al. 2011). This ANT-informed approach aligns with calls by Irumva et al. (2021) and Joshua et al. (2011) for genuine epistemological parity between IKS and conventional meteorology, rather than the tokenistic

incorporation of indigenous knowledge into scientifically dominated frameworks.

The functional use of IKS in weather forecasting is documented across diverse ecological and cultural settings globally. In north-eastern Ethiopia, Balehegn et al. (2019) documented that pastoralists employ a rich repertoire of biological and atmospheric indicators for predicting rainfall, temperature shifts, and drought, with direct implications for livestock movement and rangeland management. In western Kenya, Zachary et al. (2021) found that the Nganyi community has accumulated sophisticated rainfall prediction knowledge grounded in bio-physical and astronomical indicators, with community forecasters achieving recognition from Kenya's Meteorological Department. Rwanda's IVUBIRO system similarly integrates cloud morphology, flora, fauna, and wind patterns for seasonal forecasting, demonstrating the institutional potential of formally recognising community-based IKS practice (Irumva et al., 2021). Beyond Africa, Tahiluddin et al. (2023) documented that fishers and sailors in Tawi-Tawi, Philippines continue to rely on traditional indicators including moon halos, star configurations, and wind behaviour, reflecting evidence that IKS-based forecasting is a globally distributed phenomenon that transcends cultural and geographic boundaries. Radeny et al. (2019) synthesised evidence from across East Africa, finding that over 56% of farmers in Lushoto, Tanzania perceived IKS forecasts as more reliable than scientific alternatives for seasonal predictions, with more than 90% of respondents aware of IKS forecast practices in their communities.

Within Zimbabwe, IKS has been documented as a widespread and actively used forecasting resource despite institutional neglect. Gwenzi et al. (2016) found that over 80% of smallholder farmers across multiple Zimbabwean districts rely on IKS indicators for weather prediction, with reliance remaining strong even in communities where scientific forecasts are nominally available. This finding underscores both the depth of community trust in IKS and the persistent inaccessibility of formal meteorological services to rural end-users. Soropa et al. (2015) documented active IKS forecasting practices across Murehwa, Tsholotsho, and Chiredzi Districts, identifying specific plant, animal, and atmospheric indicators in use and

noting their role as a practical adaptation strategy for smallholder farmers navigating climate variability. Chundu and Sithole (2020) documented a diverse array of plant, animal, and atmospheric IKS indicators in Chimanimani communities, including the use of indigenous tree flowering as a predictor of imminent rainfall, while also highlighting significant decline in intergenerational knowledge transmission. Zvobgo et al. (2022) found that smallholder farmers in Chiredzi relied more heavily on IKS than on scientific forecasts for most weather parameters, particularly in communal wards, reinforcing the continued centrality of IKS in rural Zimbabwean agricultural decision-making and its significance as a climate adaptation resource.

A persistent theme in the literature concerns the accelerating threats to IKS preservation and the structural barriers that impede its integration with modern meteorology. Urbanisation, western-oriented formal education systems, and the death of elderly knowledge custodians are widely identified as primary drivers of IKS erosion across Africa (Radeny et al., 2019; Rankoana, 2022; Mbewe et al., 2019). Climate change itself exacerbates this erosion by disrupting the ecological systems upon which IKS indicators depend. Mafongoya (2018) notes that perennial droughts and temperature anomalies in Zimbabwe have shifted the behaviour of tree species traditionally used as rainfall predictors, while Soropa et al. (2015) document how accelerated climate variability has reduced the reliability of biological indicators in southern Zimbabwe, generating community uncertainty about the continued validity of inherited IKS knowledge. This creates a compounding problem, IKS is under threat precisely at a time when climate change is making accurate local forecasting most urgently needed.

At the institutional level, the integration of IKS into national forecasting frameworks faces structural barriers including divergent epistemological paradigms, language incompatibility between local IKS terminology and the technical register of scientific meteorology, limited documentation infrastructure, and the absence of government funding for IKS validation (Apraku et al., 2021; Joshua et al., 2011; Donkor et al., 2019). Joshua et al. (2011), in their landmark study of IKS integration in Malawi, demonstrated that these barriers can be overcome where bilingual facilitation teams and community weather stations are deployed, providing an important proof of concept

for the integration model proposed in this study. The absence of comparable integration initiatives in Zimbabwe, despite documented community demand (Gwenzi et al., 2016; Zvobgo et al., 2022), represents the specific policy gap that this study seeks to address.

III. METHODOLOGY

This study employed a qualitatively dominant mixed-methods case study design to investigate IKS-based weather forecasting in Ward 13, Zvishavane District, Midlands Province, Zimbabwe (approximately 20°17'S, 29°55'E). The area is a semi-arid community at 1,320 metres above sea level, characterised by mean annual rainfall of 600–800 mm concentrated in the October–March wet season. A qualitatively dominant orientation was adopted because the central research questions, concerning the nature, preservation, and integration of IKS, are inherently interpretive and context-dependent, requiring rich qualitative insight that descriptive quantitative data alone cannot adequately capture (Yin, 2018). The quantitative component provides descriptive statistical context for IKS indicator prevalence and comparative accuracy perceptions, while the qualitative component generates the depth of understanding necessary to explain community experiences, socio-cultural dynamics, and structural integration challenges. Actor-Network Theory (Latour, 1987) provided the theoretical lens for interpreting how human and non-human actors interact within IKS-based forecasting networks. Data collection was conducted during the 2024/2025 rainfall season, ensuring direct relevance to active forecasting practices.

A total of 70 participants were recruited through two complementary sampling strategies. Snowball sampling was used to identify 60 household respondents aged 46 years and above, a criterion adopted because elder community members are the primary custodians of intergenerational IKS knowledge and possess first-hand experience with long-term weather variability (Radeny et al., 2019; Mafongoya, 2018). Purposive sampling was applied to select 10 key informants with specialist knowledge of IKS, agriculture, or meteorology, comprising five community leaders, three NGO representatives, one ward councillor, and one representative from the Meteorological Services Department. Written informed consent was obtained

from all participants, and anonymity was maintained throughout the study.

Three instruments were used for methodological triangulation, and these are structured, semi-structured interviews and non-participant observation. This triangulated approach strengthens the credibility and internal validity of the findings (Yin, 2018). Quantitative data from questionnaires were analysed using SPSS and presented as descriptive frequency distributions and comparative percentages. Qualitative data from interviews were subjected to thematic analysis following the six-phase framework of Braun and Clarke (2006), with codes derived inductively and organised into overarching themes. Observation notes were used to validate and contextualise findings from both quantitative and qualitative sources. The two data strands were integrated at the interpretation stage, with quantitative descriptive findings providing the empirical backdrop against which qualitative themes were contextualised and elaborated — a convergent parallel mixed-methods integration approach (Creswell & Plano Clark, 2018).

IV. RESULTS

A. Participant Demographic Profile

A total of 70 participants contributed data to this study, comprising 60 household respondents and 10 purposively selected key informants. Table 1 presents the composition of participants by category.

Table 1. Participant composition by category

Participant Category	N=70
Households (aged 46+ years)	60
Community leaders (key informants)	5
Local NGO representatives	3
Ward Councillor	1
Meteorological Services Department representative	1
Total	70

Source: Field data, Ward 13, Zvishavane District (2024/2025 rainfall season)

Table 2 presents the demographic profile of household respondents across age, gender, educational attainment, and length of residence in Ward 13.

Table 2: Demographic profile of household respondents (n=60)

Characteristic	Category	Male (n)	Female (n)	Total (n)	Percentage (%)
Age Group	46–50 years	4	6	10	16.7
	51–55 years	8	10	18	30.0
	56–60 years	5	7	12	20.0
	61–65 years	4	6	10	16.7
	66–70 years	4	2	6	10.0
	70+ years	2	0	2	3.3
Gender	Male			27	45.0
	Female			31	51.7
Education Level	Primary	5	7	12	20.0
	Secondary	24	13	37	62.0
	Tertiary	6	5	11	18.0
Years of Residence	10–20 years	5	7	12	20.0
	More than 20 years	17	31	48	80.0

Source: Field data, Ward 13, Zvishavane District (2024/2025 rainfall season)

The modal age cohort was 51–55 years (n=18; 30.0%), reflecting the study's deliberate targeting of elder community members as primary custodians of intergenerational IKS knowledge. Female respondents slightly outnumbered males

(51.7% versus 45.0%), consistent with the demographic composition of rural Zimbabwean households where men are frequently absent due to artisanal mining and urban migration. Most respondents (80%; n=48) had resided in Ward 13 for more than 20 years, confirming deep familiarity with local ecological and atmospheric conditions essential for IKS-based weather interpretation. Educational attainment was predominantly at secondary level (62%), indicating sufficient literacy for questionnaire engagement while confirming limited formal exposure to scientific meteorology.

B. IKS Indicator Categories

Six principal categories of IKS indicators were documented through questionnaires, interviews, and direct observation. Table 3 presents the prevalence of each indicator category among household respondents.

Table 3. Frequency of IKS indicator categories reported by household respondents (n=60)

Rank	IKS Indicator Category	Frequency (n)	Percentage (%)	Key Examples Reported
1	Plant phenology	57	95	Baobab (<i>Adansonia digitata</i>) flowering patterns; early leaf emergence
2	Animal behaviour	43	72	Burchell's coucal calls; frog croaking; ant egg relocation
3	Celestial indicators	33	55	Moon halos; star configurations and phases
4	Wind direction	24	40	Southeast evening

	and humidity			winds; humid atmosphere with north winds
5	Cloud formations	22	37	Cloud morphology and colour patterns
6	Soil and insect activity	15	25	Soil moisture levels; insect emergence patterns

Source: Field data, Ward 13, Zvishavane District (2024/2025 rainfall season)

Plant phenology was the most widely used indicator (95%; n=57), with the timing and abundance of baobab tree (*Adansonia digitata*) flowering serving as the principal rainfall season predictor. Abundant early flowering was consistently associated with a good rainfall season, while late or sparse flowering signalled poor rains. Animal behaviour was the second most reported category (72%; n=43). The following participant accounts illustrate the operational specificity and accumulate empirical basis of these indicators:

"Once I see an increase in wind speed from the southeast in the evening or at night, I get to know that the following morning will be cold, windy and cloudy. I have observed this for many years, and it has not disappointed my prediction." (Participant 1)

"I have observed that if a baobab tree leaves earlier or more abundantly than usual, it is an indication that a good rain season is coming. I have seen a baobab tree flowering late or with sparse flowers; this has usually been followed by a poor rainfall season." (Participant 2)

"Increase in temperature, usually accompanied by sweating caused by a humid atmosphere, is an indication that a heavy downpour is coming on that very day. This is usually accompanied by winds coming from the north." (Participant 3)

"If I hear the rain-making bird cry during the day and this is mostly coupled with the crying of frogs at night, I know that it will rain in the coming few days." (Participant 4)

The household testimonies above were substantially enriched by the perspectives of key informants, whose specialist and institutional knowledge illuminated dimensions of IKS indicator use that quantitative frequency data alone cannot capture. Community leaders, speaking from direct experience as custodians of intergenerational ecological knowledge, contextualised the specific indicators documented in household data within the broader cultural and agricultural practices of Ward 13.

"These signs were taught to us by our fathers and their fathers before them. When I was young, my grandfather would take me to the fields at dawn and show me how to read the baobab — if it flowered early and abundantly, he would begin preparing the land without hesitation, because he knew the rains were coming. We would plant our maize, sorghum, and rapoko according to what the tree told us, not according to what anyone on the radio said." (Community Leader- Ward 13)

The Meteorological Services Department (MSD) representative offered a technically grounded perspective, acknowledging that several IKS indicators, particularly those concerning wind direction, humidity, and cloud morphology, have recognised atmospheric correlates within scientific meteorology. This acknowledgement is significant as it positions integration as scientifically feasible rather than merely aspirational. The NGO representatives, whose field presence in Ward 13 provides a mediating perspective between community practice and formal institutions, identified the urgent need to document IKS indicators before their custodians are lost as the most pressing immediate challenge facing the community.

C. Comparative Accuracy of IKS and Modern Meteorological Methods

Table 4 presents the full Likert scale response distributions across all five-forecast time-horizons, capturing respondent perceptions of the comparative accuracy of IKS relative to modern meteorological methods.

Table 4. Respondent perceptions of IKS versus modern meteorological accuracy by forecast horizon (n=60)

Forecast Horizon	Strongly Agree (%)	Agree (%)	Disagree (%)	Strongly Disagree (%)	IKS Accuracy	Modern Accuracy	Superior Method
Daily	48.0	22.0	27.0	3.0	60%	40%	IKS
Weekly	35.0	31.0	28.0	6.0	65%	35%	IKS
Monthly	6.0	8.0	48.0	38.0	40%	60%	Modern
Seasonal	34.0	14.0	8.0	44.0	45%	55%	Modern
Hazards		41.0		22.0	35%	65%	Modern

Note: Strongly Agree and Agree responses indicate perceived IKS superiority. Disagree and Strongly Disagree indicate perceived modern meteorology superiority

Source: Field data, Ward 13, Zvishavane District (2024/2025 rainfall season)

IKS demonstrated superior accuracy for short-term forecasts, with 70% of respondents agreeing or strongly agreeing that IKS was more reliable than modern methods for daily forecasts (48% strongly agreed; 22% agreed), yielding an IKS accuracy rating of 60% against 40% for modern methods. A comparable majority endorsed IKS superiority for weekly forecasts (66%: 35% strongly agreed; 31% agreed), with IKS achieving 65% accuracy against 35% for modern methods. Perceptions reversed decisively for monthly forecasts, where 86% of respondents disagreed or strongly disagreed that IKS outperformed modern methods (48% disagreed; 38% strongly disagreed), yielding a modern meteorology accuracy rating of 60%. Seasonal forecasts produced a sharply bimodal distribution: 48% perceived IKS as superior (34% strongly agreed; 14% agreed), while 52% favoured modern methods (44% strongly disagreed; 8% disagreed) reflecting contested but meaningful IKS relevance even at longer time-horizons. Modern meteorology demonstrated its strongest advantage for hazard forecasting, achieving 65% accuracy against 35% for IKS. The

complementary strengths of both systems across time-horizons were vividly captured by one respondent:

"I hear on the radio that it will rain tomorrow, but it doesn't. With indigenous signs, I can see the clouds or hear frogs and know rain is coming. But for the drought of 2023/24, the radio was correct — they told us there was going to be drought and indeed there was. Similarly in 2024/2025, they indicated that more rains were coming and the rain came."

Key informants provided institutional and technical perspectives that contextualise these comparative accuracy perceptions within Zimbabwe's meteorological infrastructure. The MSD representative was direct in acknowledging the structural constraints that limit the practical utility of scientific forecasts at the village scale. Community leaders and the ward councillor corroborated the household pattern, drawing on their broader experience of navigating between two forecasting systems across multiple cropping seasons. Their testimony added an important temporal dimension, the trust community members place in IKS for short-term forecasting is not static but is built through accumulated verification of predictions against observed outcomes over many years.

D. Socio-cultural Factors Influencing IKS Preservation

Table 5 presents the full Likert response distributions for each preservation mechanism assessed among household respondents.

Table 5. Respondent perceptions of IKS preservation mechanisms (n=60)

Preservation Mechanism	Strongly Agree (%)	Agree (%)	Disagree (%)	Strongly Disagree (%)
Traditional practices and rituals	18	82	0	0
Oral tradition and storytelling	4	8	18	73

Formal educational integration	90	10	0	0
Informal education and mentorship	0	0	90	10

Source: Field data, Ward 13, Zvishavane District (2024/2025 rainfall season)

The data in Table 5 reveals a striking divergence in community perceptions of IKS preservation mechanisms. Traditional practices and rituals received unanimous endorsement as a viable preservation mechanism, with all 60 respondents expressing agreement (82% agreed; 18% strongly agreed) and not a single respondent registering any level of disagreement. By contrast, oral tradition and storytelling were overwhelmingly rejected as currently effective by 91% of respondents (73% strongly disagreed; 18% disagreed), with only 12% expressing any level of agreement. Informal education and mentorship received the most decisive rejection of all four mechanisms, with 100% of respondents disagreeing (90% disagreed; 10% strongly disagreed) and not a single respondent expressing agreement. One respondent captured the reality succinctly:

"We don't have any structured mentorship programs for indigenous knowledge."

Key informants elaborated on the mechanisms driving this collapse of informal transmission channels, providing contextual depth that household survey data cannot fully capture. Community leaders identified specific socio-structural dynamics, including youth out-migration to artisanal mining operations and peri-urban centres, and the progressive disengagement of younger generations from subsistence agricultural livelihoods, as the primary structural drivers of the knowledge transmission breakdown in Ward 13. The ward councillor situated this erosion within the political economy of rural Zimbabwe, noting the complete absence of any government policy mechanism to recognise, support, or remunerate IKS custodians as active contributors to community climate resilience.

In stark contrast, incorporation of IKS into formal educational curricula received unanimous endorsement from all 60 household respondents (100%; 90% strongly agreed; 10%

agreed), with no disagreement recorded whatsoever, making it the single most conclusive quantitative finding in the entire study. Community participants elaborated on this institutional preference:

"I wish the government can come up with policies that allow the integration of indigenous knowledge systems and modern weather forecasting such that both methods are used hand in hand in coming up with forecasts for a specific area ranging from daily forecasts to seasonal." (Participant 1)

"There must be a way of teaching indigenous knowledge of weather forecasting in schools like how modern weather forecasting is done. That way we will be able to preserve and transfer our indigenous knowledge for use by further generations." (Participant 2)

This community demand for formal educational integration was echoed and amplified by key informants whose institutional positions allow them to identify specific and actionable policy mechanisms for implementation. The NGO representatives drew on their practical experience of curriculum advocacy and community programming to articulate what meaningful integration would require on the ground. The MSD representative similarly acknowledged the institutional value of formal educational pathways, noting that cross-training of meteorological officers in IKS indicator recognition would enhance the practical relevance of official forecasts for rural communities.

E. Challenges to IKS–Modern Integration

Five principal integration challenges were identified through thematic analysis of interview and questionnaire data. Table 5 presents these challenges ranked by frequency of endorsement across respondents.

Table 5. Principal challenges to IKS-modern meteorology integration

Rank	Challenge	Respondent Endorsement	Description
1	Language barriers	Majority agreed	Incompatibility between local Shona IKS

			terminology and scientific meteorological language
2	Divergent knowledge paradigms	Majority agreed	IKS is interpretive and experiential; modern meteorology is data-driven and probabilistic
3	Limited documentation	Majority agreed	Exclusively oral IKS transmission renders knowledge irreversibly lost upon custodian death
4	Scaling and resolution disparities	Majority agreed	IKS operates at village scale; modern forecasts issued at district or provincial level
5	Lack of institutional support	Majority agreed	IKS practitioners receive no formal recognition or remuneration unlike meteorological professionals

Language barriers emerged as the most prominently cited challenge, with respondents highlighting the fundamental incompatibility between place-specific Shona IKS interpretation and the universal technical register of scientific meteorology:

"Indigenous knowledge is based on observing local indicators which are interpreted in a local language. Modern methods of weather forecasting are universal in nature and use a universal

language. I can see a challenge in merging the two since they are based on different understandings and backgrounds." (Respondent 1)

"We need people who understand both methods very well so that they are able to interpret both. Those doing weather forecasting for a particular locality must have an in-depth understanding of the indigenous indicators of that locality." (Respondent 2)

Divergent knowledge paradigms constituted the second challenge, as illustrated by one respondent:

"I do not understand some of the meteorology jargon. For example, the met services will tell you that there is going to be scattered thunderstorms in Zvishavane. I don't even know what scattered thunderstorms are. Unlike modern weather methods, indigenous knowledge is based on what I see and the way I interpret it."

The absence of institutional support was equally stark, with IKS practitioners operating entirely outside formal recognition structures:

"Modern weather forecasting is well structured and people who give weather forecasts are gainfully employed. Unlike modern weather forecasting, indigenous knowledge systems in weather forecasting is practised at local level and there is no structure at all." (Respondent 1)

"The government should consider funding research on indigenous knowledge systems in weather forecasting so that this knowledge can be documented to preserve it. If knowledge is preserved, future generations will be able to tap into it." (Respondent 2)

Key informants whose professional roles position them at the interface between scientific institutions and rural communities articulated the structural dimensions of these integration challenges with analytical clarity. The MSD representative identified the epistemological and scaling challenges as the most technically complex from an institutional standpoint, noting the absence of any existing infrastructure for translating village-level IKS observations into formats compatible with district-level forecasting systems. The NGO representatives, drawing on their experience as intermediary actors between rural communities and formal institutions, identified the absence of a

recognised bilingual facilitation function as the single most practically urgent gap in the current institutional landscape, a finding that directly informs the bilingual communication pillar of the integration model proposed in this study.

V. DISCUSSION

This study set out to investigate the role and effectiveness of IKS in weather forecasting in rural Zimbabwe, comparing its accuracy against modern meteorological methods across five forecast time-horizons and examining the socio-cultural and institutional factors that shape its preservation and integration. The findings generate insights that are simultaneously locally grounded and internationally relevant, contributing to growing scholarly and policy discourse on the co-production of meteorological knowledge in sub-Saharan Africa.

The documentation of six IKS indicator categories, with plant phenology and animal behaviour dominating at 95% and 72% respectively, confirms and extends findings from comparable African contexts. The widespread reliance on baobab (*Adansonia digitata*) flowering patterns as a rainfall season predictor is consistent with evidence from Chimanimani, Zimbabwe, where Chundu and Sithole (2020) documented similar plant-based indicators as primary forecasting tools among rural communities. The use of Burchell's coucal calls and frog behaviour as short-term rainfall signals corroborates findings from Kenya, where Zachary et al. (2021) documented analogous bioacoustic indicators among the Nganyi community, and from Rwanda, where Irumva et al. (2021) recorded comparable animal-based forecasting practices within the IVUBIRO system. The high prevalence of plant phenology indicators in this study is particularly significant because it suggests that plant-based observation constitutes the foundational layer of IKS forecasting across diverse African ecological zones, a finding with important implications for climate-induced indicator disruption. Participant testimony in this study reveals that baobab flowering and animal behavioural signals are increasingly misaligned with observed rainfall patterns, a concern that directly corroborates Mafongoya (2018) and Soropa et al. (2015), both of whom document how accelerated climate variability is progressively undermining the reliability of biological IKS indicators in Zimbabwe. This creates a compounding vulnerability that, IKS is eroding

precisely when accurate local forecasting is most urgently needed.

The finding that IKS was perceived as more accurate than modern meteorological methods for short-term forecasts, (achieving 60% accuracy for daily and 65% for weekly predictions), while modern methods were favoured for monthly, seasonal, and hazard forecasts, is among the most policy-significant results of this study. It is important to emphasise that these accuracy figures are derived from respondent perception data rather than objective meteorological verification and should therefore be interpreted as community-level assessments of comparative reliability rather than independently validated accuracy scores. Nevertheless, these perceptions carry substantial practical significance, as it is community trust in forecasting systems that ultimately drives uptake and behavioural response to weather information (Donkor et al., 2019; Radeny et al., 2019). The bimodal distribution of seasonal forecast perceptions (with 48% favouring IKS and 52% favouring modern methods), suggests that the boundary between IKS and modern superiority is not sharply defined at seasonal scales, reinforcing the argument for complementary rather than competitive deployment of both systems. Gwenzi et al. (2016) similarly found that IKS and scientific forecasts were perceived as complementary rather than mutually exclusive by Zimbabwean smallholder farmers (Irumva et al., 2021; Joshua et al., 2011), a finding that directly informs the integration model proposed in this study.

The findings on IKS preservation mechanisms reveal a decisive and internally consistent pattern of community preference that carries profound policy implications. Traditional practices and rituals were unanimously affirmed as viable preservation mechanisms, with all 60 respondents expressing agreement (82% agreed; 18% strongly agreed) and no disagreement recorded whatsoever. This indicates that community cultural practices retain strong perceived relevance as a preservation vehicle, even as their practical effectiveness in knowledge transmission is increasingly questioned. However, oral tradition and storytelling were overwhelmingly rejected as currently effective by 91% of respondents (73% strongly disagreed; 18% disagreed), with only 12% expressing any level of agreement. Equally significant is the unanimous rejection of informal

education and mentorship as an effective preservation mechanism, with 100% of respondents disagreeing (90% disagreed; 10% strongly disagreed) and not a single respondent expressing support. These findings challenge longstanding assumptions in the IKS literature that informal mentorship constitutes a meaningful complementary channel to oral tradition in rural African communities (Radeny et al., 2019; Rankoana, 2022), suggesting that both informal transmission channels have simultaneously collapsed in Ward 13, leaving formal institutional integration as the only preservation pathway commanding community confidence. Taken together, the simultaneous rejection of both oral tradition (91% disagreement) and informal mentorship (100% disagreement) decisively contradicts the assumption prevalent in much of the IKS literature that informal transmission channels remain viable vehicles for intergenerational knowledge transfer in African rural communities (Radeny et al., 2019; Rankoana, 2022). The complete collapse of both informal preservation channels simultaneously represents a significantly more alarming finding than the erosion of oral tradition alone and substantially intensifies the urgency of the policy response recommended in this study.

In stark contrast, incorporation of IKS into formal educational curricula received unanimous endorsement from all 60 household respondents (100%; 90% strongly agreed; 10% agreed), the single most conclusive quantitative finding in the entire study. The community of Ward 13 is not passively observing the erosion of its IKS heritage, however, it is actively rejecting outmoded preservation mechanisms and demanding institutionalised alternatives. This finding signals a community-driven mandate for the Ministry of Primary and Secondary Education and the Ministry of Higher and Tertiary Education in Zimbabwe to incorporate IKS weather forecasting as substantive academic content within geography and environmental science curricula. Universities in Zimbabwe also have to lead curriculum development, professional training, and digital documentation initiatives in this domain.

The five integration challenges identified, (language barriers, divergent knowledge paradigms, limited documentation, scaling disparities, and lack of institutional support), resonate strongly with literature from across Africa, but carry urgency in the

Zimbabwean context. Joshua et al. (2011), in their landmark integration study in Malawi, identified identical barriers and demonstrated that they could be overcome through deliberate institutional investment in bilingual facilitation and community weather infrastructure. The language barrier identified in this study is simultaneously epistemological and practical, as it reflects not merely a difference in vocabulary but a fundamental divergence in how weather knowledge is produced, validated, and communicated (Mapara, 2009; Apraku et al., 2021). IKS operates through phenomenological observation and place-specific interpretation, while scientific meteorology operates through probabilistic modelling and spatially generalised communication, a divergence that Apraku et al. (2021) identify as the deepest structural obstacle to genuine knowledge co-production across sub-Saharan Africa. Donkor et al. (2019) similarly argue that without deliberate policy intervention to equalise the institutional standing of IKS practitioners relative to scientific meteorologists, integration efforts will remain superficial and unsustainable.

Viewed through the lens of Actor-Network Theory, the findings of this study reveal a deeply asymmetric network in which the processes of translation, inscription, enrolment, and black-boxing systematically privilege scientific meteorological actors while progressively marginalising IKS practitioners and the non-human actants upon which their forecasting network depends (Latour, 1987; Callon, 1986). The Meteorological Services Department functions as the obligatory passage point through which all legitimate forecasting knowledge must pass, inscribed in probabilistic models and distributed through institutional channels as immutable mobiles (Latour, 1987; Law, 1992), while IKS circulates through informal oral networks that this study demonstrates have effectively collapsed. IKS practitioners in Ward 13 have successfully enrolled a rich array of non-human actants into their forecasting network (baobab trees, Burchell's coucals, wind patterns, and frog behaviour), achieving community-perceived accuracy rates that outperform modern methods at short time-horizons (Balehegn et al., 2019; Zachary et al., 2021). Yet IKS has conspicuously failed to enrol the critical institutional actants, the MSD, the Ministry of Education, and the national policy apparatus, whose engagement would be necessary for formal integration (Apraku et al., 2021; Joshua et al., 2011). This enrolment failure is not

attributable to any inadequacy of IKS as a knowledge system, but to structural asymmetries in problematisation whereby scientific meteorology has successfully positioned itself as the indispensable solution to Zimbabwe's forecasting needs while IKS has been systematically excluded from the framing of the problem (Mapara, 2009; Leal Filho et al., 2022).

A further dimension of this asymmetry lies in the black-boxing of scientific meteorology, its methods institutionally accepted, its practitioners credentialed and salaried, its outputs distributed without requiring justification to rural communities. On the other hand, IKS remains perpetually subject to scrutiny and demands for validation not applied with equal rigour to official forecast products that this study demonstrates are perceived as less reliable than IKS at short time-horizons (Latour, 1987; Gwenzi et al., 2016; Apraku et al., 2021). Compounding this institutional asymmetry is the progressive defection of non-human actants from the IKS network, climate-induced shifts in baobab phenology and animal behaviour are dismantling the ecological infrastructure upon which IKS forecasting depends, precisely at the moment when accurate local forecasting is most urgently needed (Mafongoya, 2018; Soropa et al., 2015; Deason et al., 2022). Taken together, these ANT dynamics reframe the IKS preservation challenge not as a gradual cultural transition but as a network emergency, one in which human actants are ageing without successors, inscription infrastructure is absent, and institutional enrolment has not occurred, demanding the immediate and coordinated engagement of policy actors before irreversible network dissolution renders integration permanently impossible (Callon, 1986; Rankoana, 2022; Irumva et al., 2021).

VI. A TIERED IKS–METEOROLOGICAL INTEGRATION MODEL

Drawing on the empirical findings of this study and guided by Actor-Network Theory's emphasis on deliberate network redesign rather than knowledge replacement (Latour, 1987; Deason et al., 2022), this study proposes a Tiered IKS–Meteorological Integration Model as a practical policy instrument for Zimbabwe's climate adaptation framework. The model is grounded in the core finding that IKS and modern meteorology demonstrate complementary rather than competing strengths across forecast time-horizons. Rather than privileging one knowledge system over the other, the model assigns primary

forecasting responsibility according to demonstrated comparative accuracy at each time-horizon, while ensuring that both systems contribute meaningfully to every forecast product. This approach responds directly to calls in the literature for epistemological parity between IKS and scientific meteorology in African climate adaptation frameworks (Irumva et al., 2021; Apraku et al., 2021; Joshua et al., 2011). Table 7 presents the structural architecture of the model across three forecasting tiers.

Table 7. Tiered IKS–Meteorological Integration Model

Tier	Forecast Horizon	Forecasting Approach	Key Actors	Primary Knowledge System
1	Short-term (0–7 days)	IKS-led with meteorological support	Community elders; local weather stations	IKS primary; modern Shona and English, with meteorological verification
2	Medium-term (1–4 weeks)	Balanced IKS–modern integration	Bilingual facilitation teams; community weather committees	"Equal co-production", is functionally inaccessible to rural IKS practitioners. Bilingual facilitation teams, fluent in both Shona phenomenological description and meteorological probability language, are central actors within
3	Long-term (monthly/seasonal /hazard)	Modern meteorology-led with IKS contextualisation	Meteorological Services Department; community elders	Modern primary; IKS local verification

Source: Developed from field data, Ward 13, Zvishavane District (2025)

The model is operationalised through five interdependent pillars, each designed to directly address one or more of the integration challenges identified in this study.

The first pillar is a responsive forecasting mechanism that assigns IKS indicators primacy in Tier 1 short-term forecasts of 0–7 days (the time-horizon at which community perceptions of IKS accuracy were strongest (60% daily; 65% weekly)), with modern meteorological methods providing supporting

probabilistic context. At Tier 3, modern meteorology leads monthly, seasonal, and hazard forecasts, where it demonstrated superior community-perceived accuracy (60%, 55%, and 65% respectively), with IKS practitioners providing local ecological contextualisation and ground-truthing. Tier 2 medium-term forecasts are produced through genuine co-production, reflecting the contested and bimodal accuracy perceptions recorded at weekly to monthly boundaries in this study. This tiered allocation of forecasting authority directly addresses the scaling and resolution disparity identified as an integration challenge, by assigning each knowledge system to the time-

horizon at which it is most credible and practically actionable for rural communities (Gwezi et al., 2016; Zwobgo et al., 2022).

The second pillar is a bilingual communication strategy that requires all forecast products across all three tiers to be disseminated in both Shona and English, with meteorological concepts rendered in culturally accessible language using locally meaningful ecological analogues. This pillar directly

addresses the language barrier identified as the most prominently cited integration challenge in this study and responds to the finding that technical meteorological terminology, such as "scattered thunderstorms", is functionally inaccessible to rural IKS practitioners. Bilingual facilitation teams, fluent in both Shona phenomenological description and meteorological probability language, are central actors within

this pillar. Joshua et al. (2011) demonstrated the importance of such bilingual mediation in their Malawi integration study, finding that IKS local take-up increased substantially when meteorological information was communicated through locally meaningful language and analogues.

The third pillar comprises local weather committees at ward level, bringing together community elders, youth representatives, and meteorological officers to provide the governance architecture for the integration network. These committees serve as the institutional translation mechanism between village-scale IKS observation and district-scale modern forecasting. Simple community weather stations support this function by generating locally specific observational data, effectively bridging the resolution gap between the two knowledge systems. This governance structure responds to the

lack of institutional support identified as the fifth integration challenge, by creating a formal space in which IKS practitioners are recognised as legitimate and equal contributors to the national forecasting network alongside salaried meteorological professionals (Donkor et al., 2019). The committee structure also operationalises ANT's network design principle by creating new institutional actor-networks that translate between previously disconnected knowledge systems (Deason et al 2022).

The fourth pillar is an education and documentation programme responding directly to the most urgent finding of this study, the simultaneous collapse of oral tradition and informal mentorship as IKS preservation channels. It also responds to the unanimous community demand for formal educational integration as the preferred preservation pathway. The pillar incorporates IKS weather forecasting content into geography and environmental science curricula at secondary school and tertiary level. Additionally, it cross-trains meteorologists in the interpretation of local IKS indicators and establishes community-based digital and archival repositories for endangered indigenous knowledge before elderly custodians are irreversibly lost. Institutions of higher learning are identified as a strategic institutional anchor for this pillar. Rankoana (2022) emphasises that without systematic documentation and formal educational transmission, IKS knowledge loss becomes irreversible, making this pillar the most time-sensitive component of the entire integration framework.

The fifth pillar is an enabling policy and funding framework that provides the institutional foundation upon which the other four pillars depend. This pillar calls for the explicit incorporation of IKS weather forecasting into Zimbabwe's National Climate Change Response Strategy as a formally recognised adaptation tool, with dedicated budget lines for documentation, validation, and community weather infrastructure. It further calls for alignment with Zimbabwe's international commitments under the Paris Agreement and the Convention on Biological Diversity, both of which contain provisions for the recognition and integration of indigenous and local knowledge in national climate action frameworks. Leal Filho et al. (2022) argue persuasively that such policy formalisation is the single most

critical enabler of sustainable IKS integration across sub-Saharan Africa.

Taken together, these five pillars constitute a coherent, evidence-based, and institutionally realistic framework for leveraging the complementary strengths of IKS and modern meteorology across all forecast time-horizons. Figure 1 below presents the structural architecture of the model, illustrating how the three forecasting tiers inform the operational pillars, how Pillar 5 underpins and enables Pillars 1 through 4, how the five pillars engage key institutional actors, and how these actors collectively contribute to the desired outcome of improved forecast accessibility, accuracy, and cultural relevance for rural communities navigating climate change.

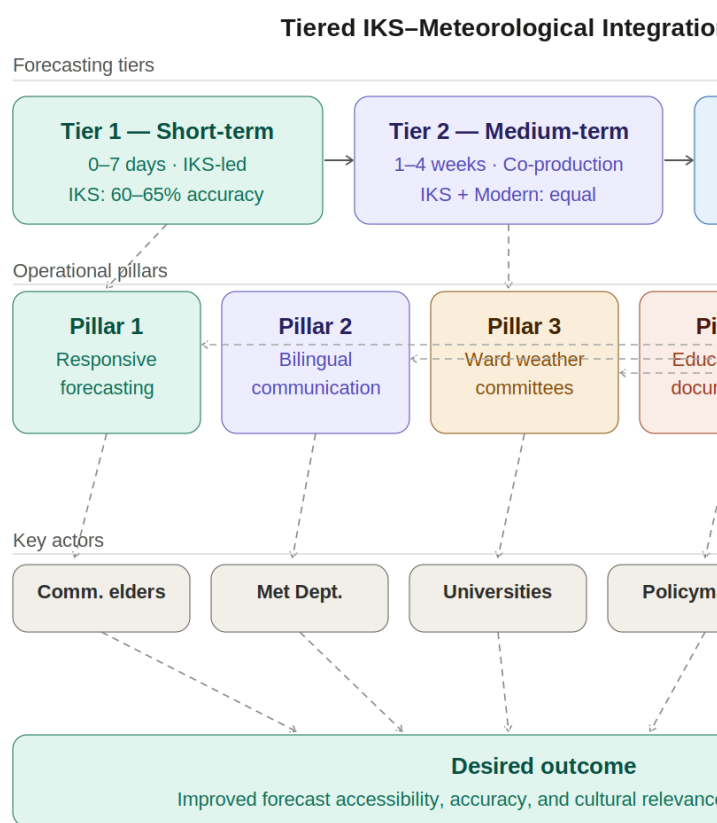


Figure 1: The Tiered IKS-Meteorological Integration Model

Source: Developed from field data, Ward 13, Zvishavane District (2025)

The model is deliberately designed for scalability beyond Ward 13. While grounded in the specific socio-ecological context of Zvishavane District, its architecture is transferable to comparable semi-arid rural communities across Zimbabwe's Midlands, Masvingo, and Matabeleland provinces.

Furthermore, its underlying principles are applicable across the broader sub-Saharan African context where comparable convergences of IKS erosion, meteorological inaccessibility, and community demand for integration have been documented (Balehegn et al., 2019; Mbewe et al., 2019; Radeny et al., 2019).

VII. CONCLUSIONS

This study set out to examine the relationship between Indigenous Knowledge Systems and modern meteorology in short-term weather forecasting in rural Zimbabwe, with direct implications for climate adaptation policy. The documentation of six active IKS indicator categories in Ward 13 leads to the conclusion that IKS-based weather forecasting is not a relic of the past but a living, operationally specific, and community-embedded practice that continues to function as a primary source of weather intelligence for rural communities in Zimbabwe. The sophistication and ecological specificity of these indicators (particularly plant phenology and animal behaviour), affirm that IKS constitutes a legitimate and structured knowledge system deserving of formal recognition alongside scientific meteorology.

The comparative analysis of forecast accuracy across five time-horizons leads to the conclusion that IKS and modern meteorology are not competing systems but complementary ones. Each demonstrates distinct strengths at different forecast scales. IKS is better suited to short-term forecasting, where locally observable ecological indicators provide timely and accessible signals. Modern meteorology, by contrast, demonstrates greater reliability at monthly, seasonal, and hazard scales, where probabilistic modelling and remote sensing data offer advantages that community-based observation cannot replicate. National climate adaptation strategies that treat the two systems as mutually exclusive therefore miss a critical opportunity for leveraging their combined forecasting potential.

The examination of socio-cultural factors influencing IKS preservation leads to the conclusion that informal transmission channels have effectively collapsed as viable preservation mechanisms in rural Zimbabwe. Oral tradition and informal mentorship can no longer be relied upon to transfer IKS knowledge across generations. Crucially, communities themselves are not passive in the face of this erosion, they are

actively demanding formal institutional alternatives. This is not merely a conclusion about knowledge loss. It is a conclusion about the readiness and willingness of rural communities to engage with institutionalised IKS preservation, a readiness that policy frameworks have yet to meet with adequate response.

The identification of five structural integration challenges leads to the conclusion that the barriers to IKS–modern meteorology integration are not technical but institutional and epistemological in nature. They cannot be resolved through goodwill alone but require deliberate, funded, and policy-mandated interventions that equalise the institutional standing of IKS practitioners alongside scientific meteorologists and create structured spaces for knowledge co-production. The proposed Tiered IKS-Meteorological Integration Model, operationalised through five interdependent pillars, provides a practical and evidence-based pathway for achieving this integration in Zimbabwe and comparable sub-Saharan African contexts.

Taken together, these conclusions affirm that the question is no longer whether IKS has a role in climate adaptation, the evidence from Ward 13 and across the African continent answers that in the affirmative. The question is whether governments, meteorological institutions, and educational bodies have the institutional will to act before the custodians of this knowledge, and the ecological systems upon which it depends, are irreversibly lost.

A. Policy Recommendations

Building on these conclusions, the study advances the following specific policy recommendations directed at key institutional actors in Zimbabwe:

First, the Government of Zimbabwe should formally incorporate IKS weather forecasting into its National Climate Change Response Strategy as a recognised adaptation tool, with dedicated budget lines for community-based IKS documentation, validation research, and local weather infrastructure. This aligns with Zimbabwe's commitments under the Paris Agreement and the Convention on Biological Diversity.

Second, the Ministry of Primary and Secondary Education should introduce IKS weather forecasting modules as

substantive academic content within geography and environmental science curricula at secondary level, moving beyond the treatment of IKS as peripheral cultural background to its recognition as a legitimate and teachable knowledge system.

Third, the Meteorological Services Department should establish formally constituted community weather committees at ward level, incorporating IKS practitioners as recognised and remunerated contributors to the national forecasting network, supported by simple community weather stations to bridge the resolution gap between village-scale IKS observation and district-scale scientific forecasting.

Fourth, higher education institutions should lead the development of community-based digital and archival documentation platforms for endangered IKS knowledge, cross-training programmes for meteorologists in local IKS indicator interpretation, and interdisciplinary research collaborations between meteorologists and IKS practitioners to develop and validate hybrid forecasting models.

Fifth, national and international development organisations operating in Zimbabwe should prioritise IKS documentation and integration as a climate resilience investment, recognising that the loss of IKS forecasting knowledge represents not only a cultural impoverishment but a tangible and irreversible reduction in rural adaptive capacity that cannot be compensated for by expanding access to scientific meteorological services alone.

B. Directions for Future Research

This study acknowledges several limitations that future research should address. The accuracy percentages reported are based on community perception data from a single ward, and independent meteorological verification studies using objective accuracy assessment methods are needed to validate these perceptions empirically. The sample size of 60 household respondents, while appropriate for a qualitatively dominant case study design, limits the statistical generalisability of the descriptive quantitative findings. Future research should extend comparative analysis across Zimbabwe's diverse agro-ecological zones, including the humid Eastern Highlands, the arid lowveld of Matabeleland South, and the high-potential

Mashonaland plateau, to test the generalisability of these findings and refine the Integration Model for national policy application. Longitudinal studies tracking changes in IKS indicator reliability under progressive climate change would further strengthen the empirical foundation for IKS-inclusive climate adaptation policy. Finally, pilot implementation and independent evaluation of the Tiered IKS–Meteorological Integration Model in Zvishavane and comparable semi-arid communities would provide the operational evidence base needed to scale the model to national level.

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