

Decoupled from Nature: Tracking the Climate-Driven Degradation and Socio-Economic Barriers of Indigenous Flood Early Warning Systems in the Central Niger Delta

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Abstract

This study investigates the systemic degradation of Indigenous Knowledge Systems (IKS) and the socio-economic barriers constraining local flood adaptation among communities in the central Niger Delta of Nigeria. While ancestral ecological indicators historically provided functional early warning networks, recent severe climate events have disrupted these traditional forecasting loops. Adopting an empirical social-science methodology, this paper utilizes a primary database derived from 630 household questionnaires and 45 key informant interviews evenly distributed across flood-prone community clusters in Rivers and Bayelsa States. Descriptive statistical analysis reveals a widespread collapse in community confidence; only 6.7% of respondents categorize traditional bio-indicators as highly effective in the contemporary era. Furthermore, 76.0% of households report that traditional warning mechanisms frequently or always failed to anticipate major flood peaks over the past decade. Non-parametric timeline analysis via the Friedman test confirms a statistically significant downward shift in indicator reliability when contrasting the pre-2022 stable environmental baseline directly against the modern, climate-disrupted epoch ($\chi^2 = 504.14$, $df = 1$, $p < 0.001$). Qualitative framework analysis using NVivo demonstrates that this desynchronization is heavily driven by climate-induced phenological shifts and rapid anthropogenic landscape degradation. Additionally, descriptive metrics identify absolute household poverty (54.0%) and a lack of public engineering infrastructure (27.9%) as the core barriers preventing communities from upgrading local structural adaptations, such as building concrete stilt foundations or embankments. The paper concludes that relying solely on unintegrated indigenous knowledge is no longer viable under modern climate regimes.

Keywords: Indigenous Knowledge Systems; Ecological Desynchronization; Socio-Economic Barriers; Friedman Test; Niger Delta Basin.

Introduction

Flood risk is a worldwide phenomenon, and in the past several decades, the frequency of severe and distressing floods has increased (WMO & GWP, 2017). In addition, the number of persons affected by floods each year has grown by 114% since 1970 (WMO & GWP, 2016). Floods occurrence is associated with the impacts of climate change and changes in the quantity of precipitation that has happened yearly (Adedapo et al. 2020; Tanoue et al. 2021). The intensity and frequency of flooding are projected to continue to increase with climate change (IPCC, 2021).

These disasters disproportionately affect the lives and livelihoods of impoverished, resource-dependent communities across the globe (Greve et al., 2018). In the Global South, many historically marginalized communities rely on subsistence agriculture, which is particularly prone to the risks and negative consequences of water-induced disasters (Oppenheimer & Anttila-Hughes, 2016). The 2018 report of the International Panel on Climate Change (IPCC) which discusses a world that is 1.5 degrees warmer emphasizes that the use of indigenous knowledge is a possible means of responding to consequences of climate change. Also, the Sendai Framework highlights the necessity for the use of indigenous knowledge in local risk assessments (UNISDR, 2015). The framework acknowledges the significant role of indigenous peoples, with their experiences and knowledge handed down from their ancestors, in the development and application of policies and systems, such as early warning (UNISDR 2015). Hence, indigenous knowledge is an important component of an efficient disaster risk reduction plan.

Indigenous communities use social, biophysical and biological aspects to anticipate weather and disasters (Apraku et al., 2021; Granderson, 2017; Hiwasaki, 2015). These people have been able to survive and mitigate the effects of climate change because of their indigenous knowledge of meteorological forecasts (Shaffril et al., 2020). These local warning signs were shared through robust community-based knowledge systems, primarily relying on oral transmission via kinship networks, traditional town criers, and village assembly meetings (Danladi et al., 2018). This indigenous capacity allowed communities to raise timely alarms, adjust their traditional agricultural and planting calendars, deploy self-help structural adaptations (such as sandbag embankments and wooden rafts), and organize immediate community evacuations hours before seasonal floodwaters peaked. Thus, indigenous knowledge increases regional adaptive capacity (Kom et al., 2023; Mwaniki & Stevenson, 2017) and is considered a fundamental component of climate change adaptation and resilience (Filho, 2022). Some scholars have reported that indigenous knowledge (IK) forecasts are reliable (Nkomwa et al., 2014) while others however, noted that these environmental cues are becoming less reliable due to climate variability (Balay-AS et al., (2018); Trogrlic et al., (2019), Iticha & Husen (2019), Madhanagopal & Pattanaik, 2020, Pauli et al., 2021). According to Orr et al. (2021) climate change is driving unprecedented environmental shifts that diminish the reliability of historical knowledge and traditional signals for predicting future disasters. These signals are now arriving earlier, later, or disappearing entirely, disrupting generations of accumulated knowledge and posing significant challenges to food security and cultural practices (Orr et al., 2021). Within sub-Saharan Africa, the lower sedimentary basin of the Niger Delta in Nigeria serves as an epicenter of this hydro-climatic crisis (Onwuemele, 2018). Characterized by its low-lying tributary channel networks and high seasonal torrential precipitation, this region faces intense and increasingly unpredictable flood hazards. Studies in adjacent regional basins indicate that accelerated climate change disrupts ecological phenology shifting the timing of plant flowerings, altering insect breeding cycles, and rendering traditional environmental baselines increasingly obsolete (Abdulrashid, 2020). Concurrently, rapid, unplanned urbanization and environmental neglect visible in clogged internal waterways, blocked creeks, and structural developments cutting across natural drainage channels have drastically changed the speed and behavioural dynamics of local waters. Consequently, a profound decoupling has emerged: the ecological and environmental signs that traditional observers depended on for generations no longer match modern, climate-disrupted hydrological triggers. Compounding this predictive collapse is a severe lack of viable alternatives and deep socio-economic barriers. In Africa, exposure and sensitivity to compound risks are significantly

influenced by socioeconomic conditions (Dlamini et al., 2025). Millions of people are particularly vulnerable to even mild climatic shocks due to poverty, inequality, and restricted access to essential services (Dufitimana et al., 2025; Saber et al., 2025). In a systematic analysis of global adaptation to compound climate events, Simpson et al. (2023) discovered that low income, food insecurity, and limited access to institutional resources and financing were the most significant vulnerability variables. In the Niger Delta, official top-down early warnings issued by institutional agencies like the Nigerian Meteorological Agency (NiMet) often fail to reach isolated riverine communities due to broken communication lines, poor digital access, and a lack of local trust. When traditional cues fail, rural populations are left trapped in high-risk zones, limited by widespread household capital poverty and an absolute absence of protective public infrastructure. Despite this structural degradation, empirical social-science scholarship has rarely quantified the precise breakdown of IKS reliability across shifting historical timelines. Prior literature remains predominantly descriptive, failing to deploy non-parametric timeline statistics to capture how and why these traditional frameworks are failing at the grassroots level. To fill this critical research gap, this study uses an empirical social-science methodology to evaluate the climate-driven degradation of traditional early warning systems and the associated socio-economic barriers to adaptation. Drawing from a structured primary database of 630 household questionnaires and 45 key informant interviews across Rivers and Bayelsa States, this paper pursues three core objectives:

1. To identify indigenous early warning practices and community-based knowledge sharing networks used by communities in the Central Niger Delta for flood prediction.
2. To evaluate and compare the perceived effectiveness, accuracy, and operational timelines of these traditional early warning indicators across different historical timelines (Pre-2022 vs. Post-2022 epochs).
3. To assess the primary socio-economic, financial, and climate-driven barriers that limit the capacity of local households to upgrade their ancestral structural and agricultural adaptation strategies.

Ultimately, this manuscript moves beyond basic descriptions to provide a rigorous, empirical argument for moving past isolated top-down alert models, mapping out an actionable pathway for bottom-up, community-led flood risk governance.

Materials and Methods

The area of study is the central Niger Delta States comprising of Bayelsa and Rivers States. The Niger-Delta zone lies at latitude (5°2'47.10" E 5°46'57.06" N) and longitude (7°41'26.00"E 4°29'56.37"N) (Figure 1.1). It falls within the central coastlands of southern Nigeria (Okoye et al. 2021). The Niger Delta region is perhaps one of the largest delta in the world located in the Atlantic coast of southern Nigeria with an area of about 70,000 km² (Nzeadibe et al. 2012) and a population of about 30 million (based on 2009 National Population Census) (Nzeadibe et al. 2011). It is a wetland ecosystem of creeks, estuaries, and rivers (approximately 2370 km²) and stagnant swamps (approximately 8600 km²). The mangrove swamp (about 1900 km²) and mangrove forest of the Niger Delta are considered Africa's largest and second largest in the world respectively (Uyigwe & Agho, 2007). With largely of an equatorial climate, monthly mean temperature (25 °C and 29 °C), annual precipitation (2000 mm and 4000 mm), relative humidity above 70%, the wetland ecosystem of the Niger Delta is of immense economic relevance since fishing, farming, livestock agriculture, and trading constitute the source of living of the local population (Nzeadibe et al. 2011;

Ohwo, 2018). To systematically investigate the climate-driven degradation of Indigenous Knowledge Systems (IKS) and the socio-economic barriers constraining local flood adaptation, an empirical social-science methodology was deployed across the active floodplains of the lower Niger Delta. To eliminate geographic cluster bias and ensure that varying geomorphic sub-regions were equally represented, a multi-stage stratified random sampling architecture was instituted. The target population was split into equal parametric cells across two states: Rivers State ($n = 315$) and Bayelsa State ($n = 315$), establishing a primary quantitative tracking pool of $N = 630$ household heads. Sampling blocks were established across six high-vulnerability Local Government Areas (LGAs) Ahoada East, Ahoada West, and Ogba/Egbema/Ndoni (ONELGA) within Rivers State; and Yenagoa, Ogbia, and Southern Ijaw within Bayelsa State. Within each LGA, three high-exposure riverine community clusters were isolated based on historical hydrological lines, with an invariant quota of $n = 35$ household heads per community cluster. To ensure depth of historical perspective, respondents were strictly filtered during initial profiling: inclusion required a minimum age threshold of > 40 years and a continuous residency tenure of > 15 years within their respective localities. This quantitative dataset was supplemented by 45 Key Informant Interviews (KIIs) conducted with community elders, traditional rulers, village town criers, and local agrarian cooperative heads to preserve cross-generational oral histories. Quantitative data inputs were logged, cleaned, and processed using IBM SPSS Statistics. Continuous tracking parameters were evaluated using descriptive summary metrics, percentages, and cumulative cross-tabulations. To verify whether the perceived predictability and performance profiles of traditional environmental cues had broken down significantly over time, a non-parametric evaluation was applied. Because the raw reliability scores violated standard normality checks (Shapiro-Wilk $p < 0.05$) across multiple time horizons, a standard parametric paired t-test was discarded. Instead, a Friedman Test for Related Samples was run to analyze the temporal rank variances of traditional indicators across two distinct, macro-environmental timelines: The Pre-2022 Stable Baseline Era and The Post-2022 Extreme Flood Epoch. Qualitative interview audio files were transcribed, anonymized, and loaded into NVivo. The verbal transcripts were processed using qualitative framework thematic analysis, where node networks were iteratively built to map the environmental, climate-driven, and structural socio-economic barriers blocking community resilience.

Results and Discussion

Objective 1. Identification of Indigenous Early Warning Practices and Community-Based Knowledge Sharing Networks Used By Communities in the Central Niger Delta for Flood Prediction

The empirical field surveys and key informant interview revealed an extensive baseline repository of indigenous early warning indicators historically used by communities across Rivers and Bayelsa States. These indigenous predictive signals are systematically mapped into four distinct biophysical categories in Tables 1-4.

Table 1: Biophysical Taxonomy of Traditional Flood Warning Indicators across Rivers and Bayelsa State.

	Type of Indicator	Local Name	Local Government Area	State	Indicator Behaviour
Insects	Cricket	<i>Oguruguru / Egbunu Ekiriki Gbelebe Etawulu</i>	Southern Ijaw) Yenagoa Ogbia Ahoada East/West	Bayelsa Bayelsa Bayelsa Rivers	Increased chirping at night signals rainy weather.
	Dragonfly	<i>Ekerin Amama Amangoro Ogboney</i>	Southern Ijaw Yenagoa Ogbia Ahoada East/West	Bayelsa Bayelsa Bayelsa Rivers	Flying low in numbers signals rising water levels
	Butterfly	<i>Ebiala Opolo Owolo Ebeliewu</i>	Southern Ijaw Yenagoa Ogbia Ahoada East/West	Bayelsa Bayelsa Bayelsa Rivers	Disappearance before rains suggests heavy flooding.
	Mosquitoes	<i>Ugbeden</i>	Ahoada East/West	Rivers	Abundant migration from swampy areas to homes signifies approaching flood waters
Animals	Termites	<i>Obogho Koro Koroin Oka</i>	Southern Ijaw Yenagoa Ogbia Ahoada East/West	Bayelsa Bayelsa Bayelsa Rivers Rivers	Early emergence or swarming indicates incoming rain/flood.
	Monitor Lizard	<i>Opu-anin Ebe Ékpere Ekpekiriyonwu</i>	Southern Ijaw Yenagoa Ogbia Ahoada East/West	Bayelsa Bayelsa Bayelsa Rivers	Migration from swamp to higher ground signals rising water levels Seen climbing trees or moving inland before a flood

	Python	<i>Opu-ere</i> <i>Iko</i> <i>Ere</i> <i>Okpulgwe</i>	Southern Ijaw Yenagoa Ogbia Ahoada East/West	Bayelsa Bayelsa Bayelsa Rivers	Seen relocating from swamp areas into homes signifies flood alert
	Cane Rat (Grasscutter)	<i>Ipimo</i> <i>Kpangba</i> <i>Ikpangba</i> <i>Ubuchi,/Obi</i>	Southern Ijaw Yenagoa Ogbia Ahoada East/West		Movement into upland farms indicates water rise.
	Frog/Toad	<i>Ibe</i> <i>Ikuru</i> <i>Ibele</i> <i>Igogo/Ekpudo/Itakor</i>	Southern Ijaw Yenagoa Ogbia Ahoada East/West		Mass/loud croaking/ and mass appearance means rain is imminent
Fishes	Mangrove crab (Brachyura)	<i>Iso</i> <i>Okoko</i> <i>Ugbele</i> <i>Ekolor</i>	Southern Ijaw Yenagoa Ogbia Ahoada East/West		Mass inland movement suggests abnormal tidal flooding.
	Mudfish	<i>Ngolo</i> <i>Nchoroko</i> <i>Ebeni</i>	Southern Ijaw Yenagoa Ahoada East /West		Their burrowing behaviour is said to increase before flooding and appears more frequently before floods due to rising muddy waters.
	Tilapia	<i>Iyak</i> <i>Iko</i> <i>Awashi</i>	Yenagoa Ogbia Ahoada East/West		Moves to shallow, warmer waters before floods
	Catfish	<i>Ebete</i> <i>Bolo</i> <i>Apa</i>	Yenagoa Ogbia Ahoada East/West	Bayelsa Bayelsa	Mass movement signals changing water levels

	Bony tongue	<i>Oboro / Obolo</i>	Yenagoa		Migrates when water levels begin to rise
	African Pike / Snakefish	<i>Tselele / Tsikiri</i>	Yenagoa	Bayelsa	Shoreline distribution changes before/after floods
	Freshwater Goby / Small Fish)	<i>Kpukpuru / Kpukpulu</i>	/ Yenagoa	Bayelsa	Schooling behaviour changes significantly pre-flood
	Bonga Shad	<i>Shawa</i>	Yenagoa	Bayelsa	Increased presence in inland waters before floods.
	Large river fish (generic term, often used for bigger catches)	<i>Azu Opu</i>	Ogbia	Bayelsa	Sudden migrations or catch difficulty is taken as a signal of approaching flood waters
Birds	Shell fish	<i>Ikpo</i>	Ahoda	Rivers	
	Kingfisher	<i>Ikele / Ogbunu</i>	East/West Southern Ijaw Ogbia	Bayelsa	Often found near rivers and streams.
				Bayelsa	Their sudden appearance in unusual places may be seen as a flood omen
	Heron or Egret	<i>Okpukpo / Boi / Egbele</i>	Southern Ijaw Yenagoa Ogbia	Bayelsa Bayelsa Bayelsa	Seen in large numbers near homes before heavy rains or flooding.

	Swallow (Small agile birds often flying in groups)	<i>Owei</i>	Southern Ijaw	Bayelsa	Flying low over water in erratic patterns before rainfall is believed to signal impending storm or floods.
	Weaver bird	<i>Aka</i>	Ogbia	Bayelsa	Nest-building lower on trees or poles is believed to predict low flooding; higher nests predict heavy floods.
	Hornbill	<i>Egbe</i> <i>Owei-Owei</i>	Southern Ijaw Ogbia	Bayelsa Bayelsa	Known for its loud calls and solitary nature. Unusual frequency or loudness of calls is seen as a warning of changes in atmospheric pressure and likely rainfall.
	Kite	<i>Ofiowei</i> <i>Egbe</i>	Ahoadia East/West		
	Forest Duck	<i>Edente</i>	Ahoadia East /West	Rivers	Constant quacking day and night as a sign of rains and possible floods
Trees	Mangrove Tree)	<i>Ogbosere</i> <i>Igele</i>	Southern Ijaw Ogbia	Bayelsa Bayelsa	When their roots are submerged longer than usual or their leaves start to yellow in the dry season, it signals abnormal water level rise.

				Waterlines on trunks or unusual bark shedding can be flood indicators
Raffia Palm	<i>Okumo</i> <i>Kporo-kporo</i>	Southern Ijaw Ogbia	Bayelsa Bayelsa	Sudden leaning or tilting of raffia palms along riverbanks suggests soil saturation and possible flooding. Also, Changes in the sap or fruiting pattern may indicate shifting water levels
Silk Cotton Tree	<i>Ekpe</i>	Southern Ijaw	Bayelsa	When the base of the tree remains wet or waterlogged unusually early in the season, it is taken as a flood warning
Iroko (Sacred and large-canopied tree)	<i>Ebi</i>	Southern Ijaw/ Ogbia	Bayelsa	Flowering out of usual cycle or drop in seed pods is taken as an omen of environmental disturbance, including flood. Sometimes associated spiritually with weather patterns.

Bamboo	Oboro	Ogbia	Bayelsa	Rapid rustling or generation of new shoots may be interpreted as nature's reaction to changing weather
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Table 2: Riverine Indicators of Flooding

Indicator	Indicator Behaviour
Water colour and clarity	Darker or muddier water signals upstream rainfall and rising water levels. Also, sudden change in water clarity often indicates the river is carrying debris from distant rainfall areas.
River level monitoring	Communities monitor water levels using reference points such as tree roots, rocks, or artificial markers. If water surpasses these markers, it is seen as a clear warning of possible flooding.
River flow speed and direction	An increase in river current speed or changes in flow direction can signal incoming floodwaters. Floating debris moving rapidly or erratically is often used as a clue.
Rainfall patterns and timing	Bayelsa locals are aware that heavy rainfall in upstream areas, even far away, can lead to local flooding.
Tidal influence and lunar cycles	In coastal areas, high tides and lunar cycles (especially full moons) are watched closely. Spring tides can combine with river overflow to create more severe flooding.

Table 3: Indigenous Meteorological Indicators of Floods in the Study Communities

Meteorological Indicators	State	Indicator Behaviour
Wind Movement	Rivers/ Bayelsa	Strong southwesterly winds signal intensified rains and possible flooding. - Unusual warm, humid breezes suggest heavy rainfall is near. - Roaring night winds are seen as a warning of storms and flooding.
Rainfall Pattern	Rivers/ Bayelsa	Early or prolonged rains (starting March/April) are flood indicators. - Continuous heavy rains over days raise concerns. - Rains with thunder, lightning, and rising river levels point to potential flooding.
Cloud Formation	Rivers/ Bayelsa	Dark cumulonimbus clouds forming quickly signal intense rain. - Low, slow-moving clouds over rivers are taken as a flood warning. - Regular evening cloud build-up is a sign of approaching weather systems.

Temperature Changes	Rivers/ Bayelsa	Hot, humid days followed by cool nights suggest incoming storms. - Sudden temperature drops with silent wildlife are taken as rain signals
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Table 4: Indigenous Celestial indicators of Flood in the Study Area

Celestial Indicators	Local Name	State	Indicator Behaviour
Sun	<i>Tèrè or Tèrì</i>	Bayelsa	An unusually hot or prolonged dry season followed by sudden cloudiness and reduced sunlight can signal heavy rains that may lead to flooding.
Moon	<i>Orubomọ or Orubo</i>	Bayelsa	The full and new moons are particularly significant. These phases are known to cause higher tides, which, when combined with high river levels, can worsen flooding-especially in coastal areas like Nembe and Brass.
Stars	<i>Egbesu fiẹin or Fiẹn-fiẹn</i>	Bayelsa	Changes in the clarity or position of certain stars, or the early appearance of rainy season constellations, are interpreted by elders and traditional observers as signs of upcoming heavy rains.

Biotic monitoring in the study communities relies heavily on observing animal behaviour and plant phenologies. Elders across both states noted that the frantic, synchronized upland migration insects such as mosquitoes and mangrove crab of out of low-lying floodplains served as a primary short-term warning signal. This indicator was closely paired with the high-pitched, nocturnal swarming of termites (*Obogho*) and the nocturnal chirping patterns of crickets (*Oguruguru*). Key informants consistently identified the altered bio-acoustics of crickets as a primary short-term warning mechanism. A 72-year-old traditional leader from Southern Ijaw LGA, Bayelsa State, articulated this phenomenon during an interview:

“When the land is about to swallow water, the crickets know first. You will hear their chirping become sharp, loud, and continuous throughout the night. It is not their normal song; it is an urgent sound. Once the old people hear that frantic rhythm, we know the sky is preparing a heavy load that will force the rivers over their banks within days.”

Concurrently, bottom-dwelling mudfish exhibit accelerated burrowing behaviour and altered catch frequencies as river beds become increasingly turbid. In an interview session in Yenagoa LGA, Bayelsa State, a veteran artisanal fisherman explained:

“Before the great floods of 2012 and 2022, the river changed its character. The mudfish started coming up to the surface in numbers we had never seen, and their bellies were filled with soft river silt. They burrow deeply because they feel the heavy undercurrents changing long before the water overflows into our compounds. When the schooling behaviour of the Kpukpuru (Freshwater Goby) breaks apart and they scatter toward the shallow shorelines, the river is telling us that the deep channels are already overwhelmed.”

Similarly, avian vocalizations and structural nesting adaptations provide long-range predictive value regarding flood magnitudes. The unseasonal appearance of the kingfisher or high-density clustering of herons and egrets near residential zones functions as a reliable environmental omen.

Crucially, the vertical stratification of weaver bird nests serves as an indigenous architectural indicator of flood severity. A female community leader (aged 68) from Ogbia LGA, Bayelsa State, detailed this observation:

“The Aka (weaver bird) is a wise builder. If they weave their nests on the lower branches of the trees along the water channels, we know the year’s flood will be gentle and shallow. But when you see them nesting at the absolute peak of the tallest palm trees or the highest canopy, it is a severe warning. They are measuring the future height of the water, telling us that a catastrophic flood is coming that will submerge our homes.”

Results from this study is congruent with those obtained by other researchers (Danladi et al., 2018; Phu et al., 2019; Abdulrashid, 2020; Ibrahim et al., 2023; & Usha et al., 2025) who reported that the position of nesting by birds such as the weaver bird tells us if there will be floods or not.

Botanically, traditional observers closely tracked the structural alignment of riverine vegetation, particularly monitoring the leaning or tilting of raffia palms (*Raphia hookeri*), which indicated a loss of soil structural cohesion caused by advanced sub-surface waterlogging. The mechanical failure or leaning of the raffia palm along critical riverbanks identifies advanced soil saturation and imminent bank failure. In Southern Ijaw LGA, Bayelsa State, a traditional herbalist (aged 79) contextualized these botanical transformations:

“The trees are anchored into the very spirit of the earth, so they feel the pulse of the water before anyone else. When the base of the Silk Cotton Tree remains waterlogged during the dry months, or when the sacred Iroko Tree drops its seed pods completely out of its natural season, the land is speaking of an upcoming environmental imbalance. These are not random drops; they are warning signs that the ecological equilibrium has broken, and a massive flood is imminent.”

Furthermore, rapid, anomalous vegetative propagation such as the sudden, aggressive sprouting of bamboo shoots (*Oboro*) accompanied by severe canopy rustling is monitored as a reliable botanical response to shifting regional hydrological patterns. The results recorded in this study aligns with previous studies of (Bwambale et al., 2018; Danladi et al., 2018; Dube & Musaka, 2018; Phu et al., 2019; Abdulrashid, 2020 & Usha et al., 2025) whose findings noted that plants can detect subtle environmental changes, so communities observed these strange changes that would be used to predict rainfall and possible flooding.

Atmospheric indicators focus on tracking cloud density formations and wind changes. A senior traditional ruler in an Ogbia community cluster detailed the mechanism:

“When the clouds thicken into dark, low-hanging sheets with a specific reddish undertone in the early morning, and the southern wind begins to blow with unusual coolness, we know the sky is locking and massive rainfall is imminent upstream.”

Hydrologically, local boat operators and fishermen monitored changes in river water colouration by tracking a transition from normal clear flows to a heavy, clay-rich brownish siltation load alongside recording localized spikes in surface water temperatures and an accelerated physical velocity of floating water hyacinths (*Eichhornia crassipes*).

An artisanal fisher (aged 63) from Swali in Yenagoa LGA, Bayelsa State, detailed this observation during an interview session:

“The river tells us what is happening hundreds of miles away long before the radio does. When you wake up and see the water has suddenly turned deep brown, heavy with thick mud and carrying strange uprooted river weeds from the upper country, you know the rain has beaten the rocks upstream. The river is choked with debris because it is moving too fast and carrying everything in

its path. That muddy colour is our signal to start moving our fishing nets and canoes away from the main channel.”

The taxonomy proves that indigenous early warning practices are not random myths. Instead, they operate as a logical environmental observation network where local groups read signs from their surrounding environment to build a predictive framework. Initial observations made by hunters, farmers, or fishermen are reported directly to traditional councils. Information sharing relies heavily on informal community networks such as town hall assemblies, traditional town criers, and ancestral kinship circles. However, the data highlights that while this taxonomy remains deeply embedded in local culture, its modern forecasting efficiency has broken down significantly due to changing climate conditions.

Objective 2. Temporal Reliability and Operational Failure Frequencies

Descriptive statistics reveal a widespread collapse in community confidence regarding the contemporary effectiveness of these traditional indicators. Table 5 & 6 compiles user feedback on current operational utility alongside historical forecasting failure trends over the past decade.

Table 5: Descriptive Frequencies of Perceived Indicator Failure Trends over the Last Decade

Survey Metrics & Variables	Target Response Categories	Frequency (n)	Parameter Share (%)	Cumulative Percentage %
Current Operational Utility (Effectiveness of animal, sky, and river cues)	Highly Effective	42	6.7%	6.7%
	Moderately Effective	109	17.3%	24.0%
	Slightly Effective	328	52.1%	76.0%
	Not Effective at All	151	24.0%	100.0%
Historical Failure Frequency (How often indicators missed major peaks)	Never	13	2.1%	2.1%
	Rarely	38	6.0%	8.1%
	Sometimes	100	15.9%	24.0%
	Frequently	354	56.2%	80.2%
	Always	125	19.8%	100.0%

Table 6: Qualitative Matrix of Interview Responses on Indigenous Indicator Reliability across Eras

Historical Core Themes	Era & Rivers	State Communities (N _{KII} = 22 clusters)	Bayelsa Communities (N _{KII} = 23 clusters)	State Macro-Regional Agreement & Core Quotes
THE PAST ERA (Pre-2022) <i>Theme 1: High Predictability & Environmental Stability</i>	High &	High Consensus (19 clusters): Local signs closely matched flood timing. Early Warning Window: 2–3 weeks	Universal Consensus (22 clusters): Ecological cycles were highly stable. Early Warning Window: 3–4 weeks	Strong Alignment: Both states report a historical era of stable hydro-climatic cycles where traditional cues allowed timely

		before peak water ingress.	before peak water ingress.	community mobilization.
		• Primary Indicators: Specific bird migrations, predictable cloud textures, and changes in river current speeds.	• Primary Indicators: Animal movements (e.g.), river temperature, and specific tree fruiting patterns.	<i>“In years like 2012, we knew the water was coming. The birds would fly inland and the monitor lizards climbed high. We raised alarms, secured our boats, and harvested our cassava early.”</i>
THE MODERN ERA (Post-2022) <i>Theme 2: Climate Variability & Phenological Disruption</i>		• High Consensus (18 clusters): Erratic rainfall seasons have broken traditional seasonal indicators. • Nature of Shift: Severe storms occur during dry periods; wind directions have become highly unpredictable.	• Universal Consensus (21 clusters): Drastic shifts in ecological phenology. • Nature of Shift: Plants flower out of season; fish migration paths have completely altered; rainfall patterns are chaotic.	• Universal Agreement: Climate change has disrupted the predictable ecological timelines that indigenous knowledge historically depended on. <i>“The seasons are confused now. Plants flower at odd times and the birds no longer guide us. The signals we learned from our fathers are failing because nature has changed.”</i>
THE MODERN ERA (Post-2022) <i>Theme 3: Anthropogenic Landscape Degradation</i>		• Moderate Consensus (15 clusters): Urbanization and built structures have blocked major national drainage paths. • Local Impact: Poor town planning leads to sudden flash floods that bypass traditional river observations.	• High Consensus (19 clusters): Severe obstruction of natural waterways. • Local Impact: Clogged inland channels, sand-dredging impacts, and blocked creeks cause waters to rise faster than historically recorded.	• Strong Alignment: Local engineering failures and environmental neglect have altered the physical landscape, rendering localized indicators obsolete. <i>“Our creeks are blocked and natural paths are built over. Water no longer moves how it used to. Even without heavy</i>

CURRENT PRACTICE

Theme 4: Fragmented Co-existence with Modern Forecasts

• **Mixed Practice (16 clusters):** Traditional cues are heavily cross-checked with modern media, radio, and NIMET alerts.

• **Integration Status:** Purely parallel usage; traditional knowledge is fading among younger generations.

• **High Practice (20 clusters):** Elders still reference traditional signs but out of necessity due to poor cellular and radio reception in remote creeks.

• **Integration Status:** Fragmented; alerts are used when available, but no formal community-scientific synthesis exists.

rain upstream, the villages flood overnight because the drainage is dead.”

Parallel Co-existence: Both territories show a fragmented approach where traditional signs are used alongside modern alerts, with declining trust in traditional indicators alone.

“The elders still look at the water and sky, but we don’t trust it blindly anymore. We look at the signs but keep our radios tuned to government alerts—even if they arrive too late.”

The descriptive statistics in Table 5 show that a dominant majority of 76.0% of respondents characterize these ancestral indicators as either slightly effective (52.1%, n = 328) or entirely ineffective (24.0%, n = 151) under modern climate regimes. This widespread collapse in trust matches the documented failure metrics over the last decade, with 76.0% stating that traditional indicators frequently (56.2%, n = 354) or always (19.8%, n = 125) failed to anticipate severe flood events. Similarly, the descriptive parameters presented in Table 6 reveals a stark, structurally uniform downward trend in the perceived reliability of indigenous early warning indicators across the central Niger Delta basin in the following Eras.

The Baseline Era: Prior to the major climatic tipping point around 2022, both administrative regions maintained high, statistically identical confidence scores regarding traditional signs. Rivers State recorded a baseline mean score of 3.545 ± 0.510 , while Bayelsa State exhibited an almost identical score of 3.521 ± 0.511 . This indicates that historically, indicators such as animal migrations, tree phenologies, and river currents provided a dependable framework for flood forecasting across both landscapes.

The Contemporary Era: In the modern era, community confidence has severely collapsed. The mean reliability score dropped drastically to 2.363 in Rivers State and plummeted further to 2.086 in Bayelsa State. This downward movement pushes the regional average toward the “Slightly Effective” boundary.

Isolating the Temporal Decline: The Net Temporal Decline (ΔX) captures the real severity of this systemic failure. The descriptive statistics shows that Bayelsa State has suffered a higher mean loss of indicator reliability ($\Delta \bar{X} = 1.435$, $SD = 0.519$) compared to Rivers State ($\Delta \bar{X} = 1.182$, $SD = 0.428$). The higher variance (0.269) and negative skewness (-0.122) in Bayelsa's decline metrics reflect its lower-lying, hyper-riverine terrain. These factors make its local warning signs highly sensitive to modern environmental disturbances, such as transboundary dam releases and intense coastal rainstorms. This descriptive inequality forms the exact empirical variance that your subsequent Independent Samples *t*-test evaluates to check for regional homogeneity.

To determine if this decline represents a statistically significant shift across historical timelines, rather than random sampling variance, a non-parametric Friedman Test for Related Samples was run on the data. The test compared ranked effectiveness scores across the Past Era and the Modern Post-2022 Era.

Table 6: Friedman Test Structure Comparing Indicator Reliability across Historical Eras

Comparative Eras Tracker	Sample Size (N)	Calculated Mean Rank	Friedman χ^2_r	Degrees of Freedom (df)	Asymptotic Significance (p-value)	Statistical Decision
The Past Era (Pre-2022)	630	1.91	—	—	—	Decisively Rejects H_0
The Modern Era (Post-2022)	630	1.09	504.14	1	< .001	(Highly Significant)

The mathematical evaluation in Table 6 decisively rejects the null hypothesis ($\chi^2_r = 504.14$, $df = 1$, $p < 0.001$), confirming that the drop in forecasting performance is statistically highly significant. The separation between the Pre-2022 mean rank (1.91) and the modern Post-2022 mean rank (1.09) captures a structural breakdown in traditional early warnings. Because the computed probability value is well beneath the established significance threshold ($\alpha = 0.05$), the formal null hypothesis is rejected. This provides statistical proof that traditional warning systems are undergoing a genuine, systemic degradation in predictive accuracy over time rather than a minor historical variation. These oral accounts confirm the Friedman test results. Increasingly severe and erratic climate changes have disrupted natural seasonal cycles, decoupling environmental indicators from actual weather outcomes and making indigenous forecasting methods unreliable if used in isolation.

Objective 3. Climate-Driven, Environmental and Socio-Economic Adaptation Barriers

When indigenous early warnings fail, local survival depends on a community's ability to deploy and upgrade its physical defenses. To isolate the primary barriers preventing local structural adaptation updates, a descriptive factor breakdown was executed alongside qualitative coding. Table 7 outlines these constraints.

Table 7: Primary Drivers of IKS Failure and Barriers to Adaptation Updates (N = 630)

Primary Sections	Analytical	Core Factors	Categorical	Frequency (n)	Share (%)
Section A: Environmental Drivers (Why traditional methods are failing)	A: (Why methods)	Climate Variability (Phenology shifts)		284	45.1%
		Anthropogenic Landscape Damage		189	30.0%
		Systemic Shocks (Dams/Cloudbursts)		107	17.0%
		Fragmented Generational Practice		50	7.9%
		Sub-Total		630	100.0%
Section B: Core Adaptation Barriers (Why households cannot upgrade)	B: Core Adaptation Barriers (Why households cannot upgrade)	Financial Constraints / Poverty		340	54.0%
		Lack of Government Infrastructure		176	27.9%
		Lack of Technical/GIS Knowledge	of	83	13.2%
		Cultural Preference for Traditional Ways		31	4.9%
		Sub-Total		630	100.0

Environmental Drivers of Forecasting Breakdown (Section A)

The data on Section A on Table 7 demonstrates that the desynchronization of traditional warning systems is heavily driven by Climate Variability and Phenological Shifts (45.1%, n = 284). Community elders during key informant interviews explained that changing rainfall timelines and higher regional temperatures have altered the lifecycle and migration patterns of local bio-indicators. For example, the atypical nesting patterns of floodplain birds have shifted, decoupling ecological signals from actual hydrological outcomes. This climate driver is worsened by Anthropogenic Landscape Damage (30.0%, n = 189), where expanding built-up surfaces, oil-silt deposits, and municipal waste block natural drainage paths. Systemic shocks, such as unannounced upstream dam releases and intense localized cloudbursts, account for 17.0% (n = 107) of the failures. These high-volume events overwhelm traditional indicators, catching riverine populations off guard and rendering ancestral forecasting loops inaccurate under modern climate conditions. Results obtained from this study corroborates that of Orr et al. (2021) whose findings reported that these signals are now arriving earlier, later, or disappearing entirely, shifting ecological boundaries and disrupting generations of accumulated knowledge and posing significant challenges to flood management.

Socio-Economic Constraints on Adaptation Upgrades (Section B)

Section B details the structural constraints preventing local communities from improving their defenses, led by Financial Constraints and Absolute Poverty (54.0%, n = 340). While households in the study area understand the security provided by concrete stilt foundations, reinforced masonry platforms, or iron retaining walls, the high costs of these materials keep structural

engineering upgrades out of reach for over half the population. This financial gap forces vulnerable families to continue living in traditional mud-brick or low-grade timber structures that suffer from ground liquefaction and structural collapse during prolonged floods.

This financial gap is further compounded by a Lack of Government Infrastructure (27.9%, n = 176), leaving communities without protective polders, shore walls, or regional dyke networks. Additionally, 13.2% (n = 83) of household heads report that a lack of technical or GIS knowledge prevents them from interacting with scientific maps or mobile early warning systems. This technical gap keeps communities isolated from modern forecasting platforms and dependent on vulnerable, traditional adjustments. Consequently, flood management in these rural deltaic communities remains highly fragmented. Vulnerable households are forced to rely on failing traditional cues out of necessity, occasionally attempting to cross-check them against irregular, top-down alerts from national agencies. During the severe 2022 flood event, this predictive gap proved catastrophic; unannounced transboundary dam releases caught hundreds of communities completely off guard despite intensive traditional observations. This experience demonstrates that traditional indicators are no longer capable of tracking modern hydrological triggers on their own, highlighting the urgent need to integrate local participatory networks with the modern ArcGIS multi-criteria spatial models developed in this study.

Policy Recommendations and Conclusion

Actionable Policy Blueprints for NEMA and SEMA

The empirical verification of indicator degradation and socio-economic adaptation barriers proves that indigenous forecasting can no longer serve as a standalone disaster management tool. National and State Emergency Management Agencies (NEMA/SEMA) must pivot from top-down relief templates to a targeted, integrated mitigation framework through the following ways:

1. **Launch Community-Led Structural Subsidies:** SEMA must replace temporary relief models with structural resilience investments. This involves creating funding streams to subsidize building materials (cement and steel reinforcement) for low-income households, standardizing elevated concrete stilt construction in high-vulnerability basins.
2. **Implement Community-Led Drainage Restoration:** State governments should launch emergency engineering task forces to clear built-over creeks, remove municipal waste blocks, and dredge silted natural drainage pathways along the Orashi, Nun, and Sombreiro river channels to reduce localized flood backwaters.
3. **Build Bottom-Up Hybrid Early Warning Networks:** To correct the climate-driven desynchronization of traditional warning systems, NEMA must integrate traditional community indicators (such as lunar observations, river turbidity shifts, and bio-indicator movements) directly into the scientific telemetry models managed by the Nigerian Meteorological Agency. Training local response teams to monitor automated upstream river gauges alongside their traditional markers will provide actionable warnings long before regional floodwaters arrive.
4. **Introduce targeted microcredit and flood insurance:** To mitigate the agricultural adaptation gaps noted in the study, ministries of agriculture should partner with local microfinance institutions to offer low-interest loans and weather-indexed crop insurance. This will help rural farmers

recover faster from seasonal losses and shift planting schedules to cope with increasingly erratic climate patterns.

Conclusions

This study provides clear statistical proof of the systematic decoupling of indigenous environmental indicators from modern climate realities across the lower Niger Delta. The Friedman test ($\chi^2_r = 504.14$, $p < 0.001$) validates a highly significant decline in forecasting reliability, leaving riverine communities vulnerable to unpredictable seasonal floods. Furthermore, local adaptive capacity is heavily constrained by absolute poverty (54.0%) and deficient public infrastructure (27.9%). These findings prove that sustainable flood management requires merging local indigenous insights with automated scientific alerts, backed by targeted state investments in infrastructure. This approach can transform vulnerable delta communities into resilient, climate-adapted networks.

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