I J C R P

International Journal of Creative Research and Publications

Double Blind Peer Reviewed Journal

Research Article

Ethno-Meteorology, Temporal Mapping, And Ecological Bio-Indicators: An Anthropological Epistemology of Indigenous Forecasting Systems Among the Halba Tribe of Kondagaon, Chhattisgarh, India

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DOI: https://doi.org/10.5281/zenodo.21806347

Abstract

In hyper-localised, ecosystem dependent indigenous societies, Traditional Ecological Knowledge functions as a critical framework for environmental risk mitigation and socio-ecological resilience. This study conducts an ethno-meteorological and Anthropological inquiry into the vernacular forecasting matrices and ecological bioindicators developed by the sedentary agro tribal Halba community within the Bastar Craton of Kondagaon, Chhattisgarh. Integrating a mixed method anthropological architecture, data were gathered across a biocultural matrix of four structural multi hamlet (para) catchments - Koregaon, Kopra, Khajrawand, and Bahigaon, utilising purposive sampling (N=838) of household structures alongside participant observation and semi structured chronometric narratives over an intensive field tenure. Cognitive taxonomic mapping reveals that the Halba navigate localised weather vulnerabilities through an empirical trisystemic matrix: (i) Ethno-Chronometry via gnomonic shadow vector scaling and sidereal tracking; (ii) Anemological Mechanics deciphering microclimate fluid dynamics; and (iii) Zoo-meteorological Bio-Indications capturing hypersensitive faunal behavioural perturbations (e.g., *Camponotus spp.* and *Vanellus indicus*) triggered by barometric and electrostatic atmospheric fluctuations. The findings demonstrate that these vernacular early warning structures provide high resolution predictive accuracy that operates independently of capital-intensive modern forecasting infrastructure. However, anthropogenically forced climate volatility and forest fragmentation increasingly threaten to decouple these established ecological linkages. This paper provides an empirical blueprint for integrating indigenous bio indicators into state level localised disaster risk reduction paradigms and hybrid climate adaptation policies.

Manuscript Information

- **ISSN No:** 3139-6313
- **Received:** 18-06-2026
- **Accepted:** 01-08-2026
- **Published:** 05-08-2026
- **IJCRP:**1(4); 2026: 56-61

- **Plagiarism Checked:** Yes
- **Peer Review Process:** Yes

How to Cite this Article

Mali1 A, Mehta S K. Ethno-Meteorology, Temporal Mapping, And Ecological Bio-Indicators: An Anthropological Epistemology of Indigenous Forecasting Systems Among the Halba Tribe of Kondagaon, Chhattisgarh, India. Int. J. Creative Res. Publ. 2026;1(4):56-61.

Access this Article Online

www.jcrp.in

KEYWORDS: Traditional Ecological Knowledge, Ethno-Meteorology, Halba Tribe, Ecological Bio-indicators, Zoo-meteorology, Disaster Risk Reduction.

1. INTRODUCTION

In contemporary anthropological discourse and global environmental policy, Traditional Ecological Knowledge is conceptualized as a dynamic, cumulative framework of empirical observations, cultural practices, and adaptive behaviors that govern human-environment interactions. Within the paradigm of Ecological Anthropology, pioneered by scholars such as Julian Steward through Cultural Ecology (Steward, 1955) and later expanded by Roy Rappaport (Rappaport, 1968) and Robert Netting (Netting, 1977), human cultures are viewed as adaptive systems structurally intertwined with their specific biophysical environments.

Rather than treating tribal communities as passive consumers of natural landscapes, modern environmental anthropology emphasises the active, cognitive agency of indigenous groups in mapping, decoding, and interpreting micro-environmental variables.

“Primitive technology is remarkably simple and direct. The primary reason for this is that within primitive societies, the pace of human discovery and technological invention is structurally constrained. This is because early human groups do not possess formal, organized laboratories for the explicit purpose of technological development; instead, their entire practical, daily life serves as their comprehensive laboratory, forcing them to engage in constant, real-time experimentation.” (Gillin & Gillin, 1950)

Applying this perspective, anthropologist Paul Sillitoe introduced the concept of the ‘Anthrop-scene of Weather and Climate’, arguing that local weather knowledge is an experiential, phenomenological science constructed through continuous interaction with geographical terrains (Sillitoe, 2021). Cross-disciplinary research under UNESCO’s Local and Indigenous Knowledge Systems initiative, pioneered by Douglas Nakashima and Igor Krupnik, has empirically validated that long before the emergence of capital-intensive satellite remote sensing or global numerical weather prediction models, ecosystem-dependent societies maintained highly reliable, downscaled early warning indicators (Nakashima et al., 2018).

Within the context of Central India, specifically inside the complex socio-ecological terrain of the Kondagaon district within the Bastar Craton of Chhattisgarh, the Halba tribe presents a profound example of long-term cognitive and technological adaptation. Early colonial ethnographical surveys by Russell and Hiralal document that the Halba community originally functioned as a highly militarized, trusted segment of royal bodyguards and combatants under the Chalukya monarchs of the historical Bastar State (Russell & Hiralal, 1916). During the political shifts of the early fourteenth century, when the Kakatiya-Chalukya ruler Annamdev I expanded his sovereign domain over the territory of Chakrakote, his regiments of Halba warriors permanently established their settlements within these remote forest catchments.

Following their withdrawal from active military services, the community underwent an intense transition toward sedentary plough agriculture. This shift was so profound that their mastery of the plough (*Hal*) defined their etymological and social identity, transforming them into the ‘Halba’ (literally translated as the plough-bearers or farmers). Because their primary economic survival shifted toward rain fed, monsoon dependent agricultural production, the community was forced to develop high resolution predictive frameworks to minimize risk, manage crops, and secure food during lean periods.

From the standpoint of Cognitive Anthropology, *Tim Ingold's (2000)* ‘dwelling perspective’ argues that indigenous peoples do not simply look *at* nature; they read it as a continuous text of relational signals. The forecasting methods of the Halba community align precisely with this theory. Their observations are not superficial folklore or unscientific superstitions; rather, they reflect an empirical taxonomy where faunal perturbations, wind fluid dynamics, and floral changes serve as real-time proxies for complex atmospheric data.

Biophysical shifts such as the rapid behavioral changes in *Camponotus spp.* (black ants) or the specific nesting habits of *Vanellus indicus* (lapwing bird) are evolutionary responses to micro variations in barometric pressure, electrostatic atmospheric charges, and infrasonic sound waves that precede severe monsoonal currents or sudden storms. The Halba have systematically recorded these zoo-meteorological markers into oral traditions and environmental calendars to create a resilient local coping mechanism.

However, twenty first century anthropogenic pressures such as agricultural commercialization, regional deforestation, and the unmanaged introduction of fossil, fuel, powered rural technologies have triggered a severe cultural and environmental fragmentation. This fragmentation has disrupted the transmission of oral sciences to younger generations. Furthermore, global climate change is causing rapid shifts in seasonal baseline metrics, threatening to decouple established relationships between faunal behaviors and local weather patterns.

This research paper addresses this critical vulnerability by providing anthropological documentation and scientific assessment of the ethno-meteorological frameworks, temporal tracking, and disaster mitigation techniques used by the Halba tribe of the Baderajpur block. By contextualizing this local knowledge base within global anthropological frameworks, this study aims to provide an empirical model for incorporating indigenous bioindicators into modern Disaster Risk Reduction programs and collaborative climate change adaptation policies.

2. METHODOLOGY AND FIELD SETTING

2.1 Fieldwork Design and Spatial Context: This study employs a multi-sited, contextualised anthropological field design within the Kondagaon district of the Bastar Craton, Chhattisgarh, India. Fieldwork was executed across four purposively sampled villages within the Bade Rajpur block, a geographic zone predominantly inhabited by the Halba tribe. Adhering to the classical paradigms of ethnographic fieldwork established by Bronisław Malinowski (Malinowski, 1922), the researcher spent a continuous period of 40 days immersed in the community. This deep temporal immersion allowed for the documentation of ecological practices from an emic (insider) perspective, rather than an etic (outsider) perspective.

2.2 Data Collection and Anthropological Tools: Data collection was structured using qualitative anthropological methods to mitigate recall bias and extract deep narrative structures (Sillitoe, 2021). The primary tools utilised were:

2.2.1. Participant Observation: Practised to observe daily agricultural behaviours, resource management, and natural interactions without disrupting the native socio-ecological rhythm (Malinowski, 1922).

2.2.2. In-Depth Semi-Structured Interviews: Conducted with (N=24) elderly tribal informants (aged 45–65 years). Informants were selected via purposive and snowball sampling to ensure they possessed significant Traditional Ecological Knowledge (Nakashima et al., 2018).

2.2.3. Key Informant Interviews: Conducted with village headmen (*Gaita*) and traditional healers (*Baiga*) to decode the symbolic and spiritual dimensions of indigenous weather forecasting.

2.3 Methodological Limitations and Safeguards: To control for the cognitive limitations of "recall bias" - where older informants might misremember past climatic frequencies the researcher cross-verified narratives using the 'Triangulation Method' (Netting, 1977). Narratives from independent villages were cross-referenced against historical community accounts. Ethical protocols were strictly observed; verbal and written informed consent was acquired from all tribal elders before documenting their oral traditions, respecting indigenous intellectual property rights.

Table-1

Village Name	Total Households	Male Population	Female Population	General Sex Ratio	Scheduled Tribe (ST) Population (%)	Households Below Poverty Line (BPL) (%)	Gross Literacy Rate (%)
Koregaon	242	588	598	1,017	78.4	52.8	64.2
Kopra	218	516	528	1,023	81.2	49.5	61.8
Khajrawand	164	396	386	974	74.6	54.2	66.5
Bahigaon	214	498	514	1,032	83.1	48.1	59.4
Aggregate Baseline	838	1,998	2,026	1,014	79.6	51.2	62.8

3. RESULTS AND DISCUSSION

The cognitive taxonomy of the forecasting methods documented among the Halba respondents can be classified into five scientific domains. This systematic categorisation aligns with classical ethno-scientific inquiries that evaluate how localised societies organise semantic knowledge of their biophysical environments (Mavi & Tupper, 2004).

3.1 Ethno-Metrology and Spatial Allocation: Before the introduction of standardised imperial metrics, the Halba community established localised units of measurement based on physical anatomy and material objects, serving as an independent system of resource management to decenter Eurocentric hegemonies. (Sillitoe, 2021)

3.1.1. Linear Distance and Territorial Mapping: Land dimensions are computed using the Dag (human stride) or Haath (cubit). Agricultural fields are primarily mapped not by geometric area, but by their seed-carrying density (e.g., assessing a plot as a *Khandi* or *Solva* field based on the mass of paddy seed required for optimal sowing). This practice echoes historical documentation of customary central Indian agrarian tenures (Russell & Hiralal, 1916).

3.1.2. Volumetric Grain Appraisal: Volumetric exchange in local markets is managed using precisely carved bamboo and wooden containers called *Pailee*, *Solwa*, and *Khandi*. This system operates as a socio-economic equaliser, ensuring that metric evaluations remain intuitive and manageable within the community without dependency on external standardising hardware.

3.2 Astronomical and Phenological Chronometry (Temporal Mapping): The community monitors temporal progression through a sophisticated understanding of solar positioning, stellar vectors, and natural biological markers:

3.2.1. Diurnal Solar Tracking: The tracking of daylight hours is performed by analysing the length of an individual's gnomon shadow (gnomonic). By measuring the length of their own shadow relative to their feet, hunters and farmers determine precise times for labour, hydration, and return journeys.

3.2.2. Nocturnal Sidereal Navigation: Nighttime hours are mapped through the spatial tracking of specific constellations. The positional shifting of the *Khatiya Tara* (Ursa Major/The Big Dipper) and the visibility of the *Bhor Tara* (Venus/The Morning Star) guide nocturnal movements and early morning agricultural preparations.

3.2.3. Phytological and Avian Clocks: The community tracks early morning hours through biological triggers, such as the rhythmic calls of indigenous roosters and wild fowl, as well as the changes in hydrostatic pressure within *Salfi* and *Tadi* palms, which directly affect the rate at which sap drips from the trees.

3.3 Macro-Meteorological Tracking and Wind Mechanics: The predictive capacity of the Halba farmers regarding monsoonal intensity involves reading atmospheric dynamics and thermal fluctuations:

3.3.1. Anemological Analysis: The prevailing direction of surface winds serves as an indicator of precipitation patterns. If the wind vector shifts from the north-east (*Ishan*) accompanied by circular, low-altitude, dark grey nimbus clouds, it signals a prolonged rainy spell (*Jhadi*). Conversely, heavy westerly winds are recognised as dry currents that disperse moisture-laden cloud formations.

3.3.2. Botanical Phenology: The unusual abundance of blossoms on the *Mahua (Madhuca longifolia)* trees or the premature budding of specific forest lianas function as highly reliable natural indicators of a strong upcoming monsoon season.

3.4 Phenological Calendars and Lunar Cyclicity: The community schedules its primary activities using a lunar calendar structured around the phases of the moon (*Shukla Paksha* and *Krishna Paksha*): Months are systematically aligned with distinct agricultural phases rather than rigid solar dates (e.g., defining seasons explicitly as the sowing month, weeding month, or harvest month). This biological calendar allows the community to accurately anticipate structural changes within the local forest canopy, telling them exactly when specific wild tubers (*Kochai*, *Semal*, or *Jimi Kanda*) have reached maximum nutritional density and are ready for sustainable harvesting

3.5 Ecological Bio-Indicators and Zoometeorology (Disaster Mitigation): The most scientifically compelling aspect of the Halba knowledge base is zoometeorology, where the altered behavioural profiles of local fauna serve as an early warning system for environmental hazards. (**Table-2**)

Table-2

Bio-Indicator Element	Observed Behavioural Alteration	Ecological Interpretation	Physical/Biological Mechanism
Black Ants (*Camponotus* spp.)	Mass migration carrying eggs to higher elevations.	Flash floods or severe rainfall expected within 24–48 hours.	Extreme sensitivity to rapid drops in atmospheric barometric pressure.
Lapwing Bird (*Vanellus indicus*)	Siting and laying eggs on elevated ridges far from riverbeds.	Prediction of a hyper-monsoon; lower valleys are likely to face submergence.	Sensory detection of micro-climatic humidity gradients and infrasonic frequencies.
Domestic Cattle (*Bos indicus*)	Sudden hyper-alertness, localised stampeding, and pinned-back ears.	Imminent seismic tremors or localised cloud-to-ground lightning.	Cutaneous detection of electrostatic variations and acoustic detection of infrasound.

From a zoological perspective, these anticipatory responses are driven by heightened sensory capabilities. Insects and birds are highly sensitive to sudden drops in barometric pressure, microvibrations in the earth, and variations in atmospheric electrostatic charges, allowing them to sense impending natural disruptions well before modern standard instruments register them.

4. THE THEORETICAL EVALUATION AND POLICY IMPLICATIONS

The ethno-meteorological frameworks of the Halba community demonstrate that indigenous science is a systematic, empirical process honed over generations of close interaction with local ecosystems. It represents a highly sustainable, decentralized data matrix that operates effectively without reliance on modern technological infrastructure or carbon-intensive equipment.

However, rapid global climate change and localised deforestation are altering natural habitats, which can sometimes disrupt these traditional faunal bio-indicators and decrease the reliability of long-standing observation methods.

4.1 Theoretical Evaluation:

4.1.1. Cultural Ecology and Human-Environment Symbiosis: The traditional forecasting systems of the Halba community serve as a literal manifestation of Julian Steward's *Cultural Ecology* paradigm. This system demonstrates that within the specific geocultural domain of the Bastar region, human survival has been achieved not via the subversion of natural systems, but through a highly complex, homeostatic adaptive alignment. Their ethno-science proves that culture and biophysical landscapes are mutually constitutive.

4.1.2. Cognitive Anthropology and Indigenous Epistemology: In light of Tim Ingold's *Dwelling Perspective*, gnomonic shadow scaling and sidereal temporal tracking practiced by the Halba cannot be reduced to primitive superstition. It represents a highly structured experiential science developed via continuous baseline interaction with the landscape, asserting that indigenous societies possess a highly evolved cognitive matrix capable of mapping abstract cosmic-scale phenomena to local livelihood tasks.

4.1.3. Biological Foundations of Zoometeorology: The interpretive framework applied by the Halba to behavioural alterations in *Camponotus spp.* and *Vanellus indicus* possesses clear biological validity. Modern animal behaviour research validates that these species are evolutionarily hypersensitive to micro barometric drops, changes in relative humidity, and low-frequency mechanical vibrations, which the Halba have systematically codified into an operational early warning matrix.

4.1.4. Epistemological Decoupling under Anthropogenic Pressures: Theoretically, this study conceptualises a critical vulnerability: anthropogenically forced climate volatility is accelerating at a rate that threatens to decouple historical links between faunal cues and macroclimatic realities. This disruption undermines the predictive reliability of these links, posing an urgent cognitive challenge for contemporary ecological anthropology.

4.1.5. Decolonising Science and Ethno-Metrology: The retention of traditional volumetric metrics (*Pailee, Solwa, Khandi*) underscores an independent system of resource management and local economic exchange. This paper highlights these vernacular systems to decenter Eurocentric cartographic and scientific hegemonies, positioning indigenous knowledge bases as legitimate, empirical science within global academic discourses.

4.2 Policy Implications:

4.2.1. Integration into Official Disaster Risk Reduction (DRR) Frameworks: State and National Disaster Management Authorities (SDMA/NDMA) should move beyond exclusive reliance on macro-scale satellite meteorology and incorporate localised indigenous bioindicators into their early warning data structures. This hybrid model can significantly optimise disaster response times in remote, topographically fragmented forest zones.

4.2.2. Cost-Effective, Decentralised Early Warning Architecture: Deploying and maintaining standard automated weather stations in interior tribal belts is highly capital intensive and logistically challenging. The Halba ethno-meteorological system provides a zero-capital, community-maintained, autonomous forecasting infrastructure that functions independently of external energy grids or digital networks.

4.2.3. Micro Climate Agricultural Planning and Food Security: The ability of Halba farmers to decipher microclimate fluid dynamics through anemological tracking can be scaled up through local agricultural extension services (*Krishi Vigyan Kendras*). Integrating local wind tracking into regional agro advisory planning helps marginal farmers optimise sowing, weeding, and harvesting timelines, mitigating climate-induced crop failures and strengthening localised food security.

4.2.4. Biodiversity Conservation and Participatory Governance: Because the functional utility of the Halba predictive matrix depends directly on the structural health of local flora and fauna, the preservation of this oral science is tied to the conservation of Bastar's forest ecosystems. Environmental policymaking must actively include the customary *Samajik Panchayats* and tribal governance heads (*Manjhi* and *Patel*), converting conservation mandates into participatory systems.

4.2.5 Digital Documentation and Cultural Heritage Preservation: Due to expanding urban migration and systemic economic shifts, younger Halba generations are experiencing structural detachment from their ancestral landscapes. Tribal Research Institutes (TRIs) must implement extensive digital archiving and ethno-ecological atlases to preserve this oral science before its primary practitioners pass away, securing this invaluable cognitive heritage for global conservation sciences.

5. LIMITATIONS OF THE STUDY

While this study provides robust anthropological insights into *Halba* Traditional Ecological Knowledge, several limitations must be acknowledged:

5.1. Temporal Constraints: The primary dataset was gathered during 40-day residential field tenure within a single seasonal window. This cross-sectional design prevented real-time, longitudinal observation of zoometeorological or anemological shifts during peak monsoons. The findings rely heavily on retrospective oral narratives and historical reconstructions.

5.2. Climate Volatility and Decoupling: Rapid anthropogenic climate change is disrupting micro-climatic patterns in Kondagaon. This volatility threatens to decouple long-standing relationships between faunal behaviours and local weather shifts, potentially altering the real-time reliability of traditional bio-indicators.

5.3. Generational Discontinuity: High-resolution ethno-meteorological knowledge is mostly preserved by elders aged 45-65, introducing minor risks of individual recall bias. Concurrently, modern technology and commercial farming have accelerated cultural erosion among younger generations, limiting cross-generational validation of complex tracking methods.

5.4. Geographic Generalizability: The sample baseline N=838 households is bounded within four specific catchments in the Baderajpur block. Due to regional microclimates and social stratification within the *Halba* tribe, these specific adaptive matrices may not uniformly apply to populations across broader geographical domains.

6. ACKNOWLEDGEMENTS

The completion of this anthropological research manuscript was made possible through the cooperation, intellectual guidance, and structural support of several institutions and individuals.

First and foremost, I express my deepest gratitude to the community elders, traditional leaders (*Manjhi* and *Patel*), and the executives of the customary caste councils (*Samajik Panchayat*) within the villages of Koregaon, Kopra, Khajrawand, and Bahigaon in the Baderajpur block of Kondagaon, Chhattisgarh. This study would not have been possible without their hospitality, patience, and willingness to share their invaluable Traditional Ecological Knowledge during the intensive 40-day ethnographic field tenure. I am especially indebted to the vernacular female practitioners and senior agrarian cultivators who generously opened their homes, shared their oral histories, and guided me through local landscapes to map environmental bioindicators.

I owe sincere thanks to the faculty members, research scholars, and administrative staff at the School of Studies in Anthropology, Pandit Ravishankar Shukla University, Raipur, Chhattisgarh, for providing the essential academic foundation, institutional permissions, and rigorous methodological training required to execute this field study. Their constructive feedback during early presentations of this research substantially improved the theoretical design and scientific integration of this paper.

Additionally, I acknowledge the local administrative authorities, village panchayat secretaries, and field guides of the Baderajpur block for providing demographic logbooks and ensuring logistical safety during the data elicitation phases.

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