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Guardians of the Forest: Indigenous Ecological Knowledge and Climate Adaptation Strategies among Tribal Communities in Central-Eastern India

Anubhav Samarth[1]

ABSTRACT

Increasing precipitation anomalies and climate volatility severely disrupt rain-fed agrarian livelihoods across Eastern India. Grounded in Fikret Berkes's Sacred Ecology and Social-Ecological Resilience frameworks, this qualitative ethnographic study examines autonomous climate adaptation among the Munda and Oraon tribal communities of the Chota Nagpur Plateau, Jharkhand. Based on semi-structured interviews (N = 38), focus group discussions, and participant observation across three rural blocks (Bero, Mandar, and Khunti), the study identifies three core pillars of Indigenous Ecological Knowledge (IEK): (1) ethno-meteorological forecasting via bio-indicators (faunal behavior, avian nesting, and floral phenology); (2) micro-topographical agro-biodiversity through drought-resilient millets (Madua, Gondli); and (3) community governance anchored in sacred groves (Sarna) and reciprocal labor networks (Madat). The findings indicate that IEK offers granular, place-based climate buffers that complement macro-level meteorological models. However, intergenerational attrition and unprecedented climate shocks threaten knowledge continuity. The paper highlights the critical need to integrate indigenous indicators, customary institutions, and decentralized seed banks into formal state climate action plans.

Keywords: *Indigenous Ecological Knowledge (IEK), Climate Resilience, Ethno-meteorology, Sacred Ecology, Agro-biodiversity, Environmental Anthropology, Chota Nagpur Plateau*

Anthropogenic climate change poses existential threats to agrarian livelihoods, disproportionately affecting indigenous populations whose subsistence depends directly on

[1] Researcher, Amaltas University, Dewas, Madhya Pradesh

climate-sensitive ecosystems (IPCC, 2022). In regions such as the Chota Nagpur Plateau of Eastern India, erratic monsoon patterns, prolonged dry spells, and seasonal temperature anomalies disrupt rain-fed agro-ecosystems and traditional cropping calendars. While global climate mitigation strategies predominantly rely on techno-scientific, top-down interventions, an increasingly critical body of ecological anthropology argues that such models frequently disregard the contextual realities of marginalized rural populations (Agrawal, 1995; Dove, 2014). For indigenous groups such as the Santhal, Munda, and Oraon, environmental adaptation is not solely a technical dilemma; it is deeply embedded in place-based ecological interactions cultivated across generations.

Indigenous Ecological Knowledge (IEK), often conceptualized as Traditional Ecological Knowledge (TEK), represents a cumulative body of knowledge, practice, and belief regarding the relationship of living beings with one another and with their environment, evolving through adaptive processes and handed down through cultural transmission (Berkes, 2018). Unlike abstracted modern meteorological forecasting, IEK encompasses a holistic, observational understanding of local bio-indicators, soil micro-ecologies, and hydrological patterns. Indigenous communities employ fine-grained ethno-meteorological observations, such as insect reproductive behavior, avian nesting elevations, and tree phenology, to predict monsoon trajectories and calibrate sowing schedules (Reyes-García et al., 2016; Roncoli et al., 2002). Furthermore, localized agricultural biodiversity, reflected in the preservation of drought-hardy millet cultivars (Eleusine coracana, Paspalum scrobiculatum) and landrace paddies, functions as an autonomous buffer against harvest failure (Altieri et al., 2015).

Theoretically, this inquiry is situated within Fikret Berkes's (2018) Sacred Ecology framework, which conceptualizes traditional environmental engagement across four interrelated levels: local empirical knowledge of animals and plants, resource management systems, social institutions of collective governance, and a cultural-cosmological worldview. Within tribal communities, ecological stewardship is inseparable from social and cosmological institutions. Customary regimes of land conservation, exemplified by Sarna (sacred groves), institutionalize community-enforced taboos against excessive extraction, preserving local biodiversity sanctuaries and recharge points for aquifers (Gadgil et al., 1993; Malhotra et al., 2001).

Complementing this perspective, Social-Ecological Resilience Theory (Folke, 2006; Berkes et al., 2003) frames resilience as the capacity of complex, linked human-nature systems to absorb disturbance, reorganize, and maintain fundamental structures and functions amid ecological stress. Rather than treating vulnerability as a passive condition, this lens illuminates indigenous communities as proactive agents utilizing shared social capital, communal labor-sharing (Madat), and adaptive agro-forestry to navigate systemic shocks. Consequently, examining the interface between empirical folk observation and cultural institutions addresses a critical empirical gap: how indigenous knowledge systems function as dynamic, resilient mechanisms of climate adaptation rather than static relics of the past.

METHODOLOGY AND FIELD SETTING

Study Area and Cultural Context

This study was conducted across three rural blocks, Bero, Mandar, and Khunti, situated within the Chota Nagpur Plateau region of Jharkhand, Eastern India. Geographically, this terrain is characterized by undulating lateritic plateaus, dry-deciduous forest tracts (*Shorea robusta* dominants), and rain-fed subsistence agro-ecosystems. The socio-ecological landscape is predominantly inhabited by the Munda and Oraon tribal communities, whose customary survival strategies are intricately tied to seasonal forest products and rain-fed terrace farming (*don* and *tanr* land divisions). Over the past two decades, this geo-climatic zone has experienced marked micro-climatic disruptions, including prolonged mid-monsoon dry spells, delayed onset of the South-West monsoon, and dwindling groundwater tables, presenting acute operational challenges to traditional agrarian routines.

Research Design and Epistemological Framework

To capture the tacit, contextual nuances of Indigenous Ecological Knowledge (IEK), this investigation adopted an ethnographic, qualitative-descriptive research design grounded in interpretive phenomenology (Creswell & Poth, 2018; Geertz, 1973). Rather than evaluating indigenous wisdom exclusively against Western meteorological standards, this design prioritized community-defined environmental perceptions, linguistic classifications, and intergenerational practices as legitimate empirical realities.

Component	Methodological Choice	Justification
Research Design	Qualitative-interpretive ethnography	Unpacks tacit ecological knowledge and lived adaptation strategies
Field Sites	Bero, Mandar, and Khunti blocks (Jharkhand)	High density of tribal populations; acute agro-climatic variability
Sampling Approach	Purposive and snowball sampling ($N = 38$)	Captures generational memory, institutional roles, and gendered practices
Data Collection	Semi-structured interviews, FGDs, participant observation	Triangulates oral accounts with physical agrarian and ecological rituals
Analytical Lens	Inductive thematic analysis via Braun & Clarke (2006)	Systematically categorizes grounded narratives into coherent themes

Sampling and Informant Selection

A non-probability, purposive sampling strategy combined with snowball sampling was employed to identify participants possessing specialized ecological, agricultural, and cultural memory ($N = 38$). Informants were stratified across three key categories:

1. **Traditional Knowledge Holders & Elders (n = 14):** Male and female elders (aged 55–80) with comprehensive longitudinal knowledge of historical weather patterns, flora-fauna phenology, and customary rituals.
2. **Community Leadership & Ritual Specialists (n = 8):** Traditional village heads (*Mundas/Mahtos*) and ritual priests (*Pahans*), custodians of sacred grove management and seasonal taboos.
3. **Active Subsistence Farmers & SHG Members (n = 16):** Smallholder farmers, with dedicated inclusion of women associated with Self-Help Groups (SHGs) managing household seed preservation, domestic water storage, and wild foraging.

Data Collection Techniques

Data generation was executed between June 2025 and November 2025 to synchronize with the monsoon agricultural cycle (*Kharif* season), employing three complementary anthropological techniques:

- **In-Depth Semi-Structured Interviews:** One-on-one sessions (45-75 minutes) conducted using an open-ended interview guide translated into regional dialects (Sadri and Mundari). Discussions concentrated on ethno-meteorological predictors (e.g., bird nesting, wind shifts, insect behaviors), soil moisture conservation, seed selection, and communal safety nets.
- **Focus Group Discussions (FGDs):** Four interactive FGD sessions (6-8 participants each) were conducted, two mixed-gender groups exploring village-level resource allocations, and two women-only sessions evaluating wild famine-food harvesting and domestic water rationing during drought.

- **Participant Observation:** The researcher engaged in immersive field visits during key agricultural preparation phases, community desilting of local water harvesting structures (*dobhas* and check-dams), and the observance of seasonal ecological ceremonies (such as *Sarhul* and *Karam*), maintaining detailed reflective field journals.

Data Analysis and Trustworthiness

Audio recordings and transcribed notes were systematically translated into English and processed through six-phase inductive thematic analysis (Braun & Clarke, 2006). Transcripts were iteratively open-coded to generate candidate codes (e.g., *ant movements as rainfall indicators*, *millet drought resilience*, *pahan forest injunctions*), subsequently synthesized into broader conceptual themes mirroring the study's analytical aims. Methodological rigor was reinforced through source triangulation across methods, prolonged field presence, and member-checking meetings with community elders to confirm accurate interpretation of cultural terms.

Ethical Considerations

The study adhered strictly to standard ethical protocols for social science research. Prior informed consent was obtained orally or in writing from all informants and community councils (*Gram Sabhas*). Informants were apprised of their voluntary participation and granted full rights of withdrawal. Pseudonyms were instituted to safeguard informant identities and maintain the confidentiality of sacred and customary sites.

Findings and Thematic Analysis

The qualitative and ethnographic data gathered across the study sites yielded three overarching themes illustrating how indigenous ecological knowledge (IEK) structures community resilience in the face of climatic variability: (1) ethno-meteorological forecasting and ecological semiotics, (2) adaptive agro-biodiversity and customary hydrological management, and (3) institutional stewardship through sacred ecology and collective labor mechanisms.

Theme 1: Ethno-Meteorological Indicators and Ecological Semiotics

Informants demonstrated a sophisticated, empirical system of localized forecasting based on bio-indicators, atmospheric cues, and floral phenology. Rather than perceiving weather as an isolated stochastic event, communities interpret subtle ecological shifts as predictive semiotics for calibrating agricultural cycles.

Category	Observed Ecological Indicator	Folk Interpretation / Agricultural Action
Faunal Behavior	Black ants (*Haplorhynchus* spp.) moving eggs upwards to higher earthen bunds	Imminent torrential downpour within 24-48 hours; prompt preparation of drainage channels
Avian Phenology	Low-altitude nesting of the Red-wattled Lapwing (*Vanellus indicus*) on field margins	Scant monsoon projection; farmers shift investment toward coarse millets over paddy
Floral Phenology	Profuse, synchronized early blooming of the Sal tree (*Shorea robusta*) during *Sarhul*	Prognosis of a timely, balanced rainy season; signals commencement of upland plowing
Atmospheric Shifts	Sustained eastern wind (*Purwa*) carrying evening low-altitude cumulonimbus formations	Onset of active monsoon surge; immediate seedling nursery preparation

Informants underscored that these observations are cross-verified across multiple signs. As an elder farmer (*Pahan*, age 67) remarked:

"The radio (indicative word for mobile and television) tells us it will rain in the district, but the clouds wander off. When the termites sprout wings and the Sal canopy opens in unison, the soil is ready. Our grandfathers timed their ploughs to the forest, not to town clocks."

Theme 2: Adaptive Agro-Biodiversity and Traditional Water Governance

To counter erratic rainfall intervals and recurrent mid-season dry spells, informants rely on risk-spreading strategies rooted in traditional crop genetic diversity and micro-topographical land management.

Preservation of Hardy Crop Landraces

Subsistence households maintain a tiered cropping architecture. While low-lying depressions (*don* lands) are reserved for native, medium-duration rice varieties, the dry uplands (*tanr* lands) are intentionally planted with indigenous drought-resistant millets and legumes:

- **Finger Millet (*Eleusine coracana*, locally *Madua*):** Celebrated for low transpiration needs and prolonged storage viability (retained up to five years as a buffer against food deficits).
- **Little Millet (*Panicum sumatrense*, locally *Gondli*):** A short-duration crop (maturing in 60-65 days) harvested during the lean pre-harvest window when standard grain supplies dwindle.
- **Mixed Cropping (*Bera* cultivation):** Intercropping pulses like Pigeon pea (*Cajanus cajan*, *Arhar*) with maize to preserve soil nitrogen and secure at least one harvestable yield if precipitation fails abruptly.

Traditional Hydrological Systems (*Dobhas* and *Ahar-Pyne* remnants)

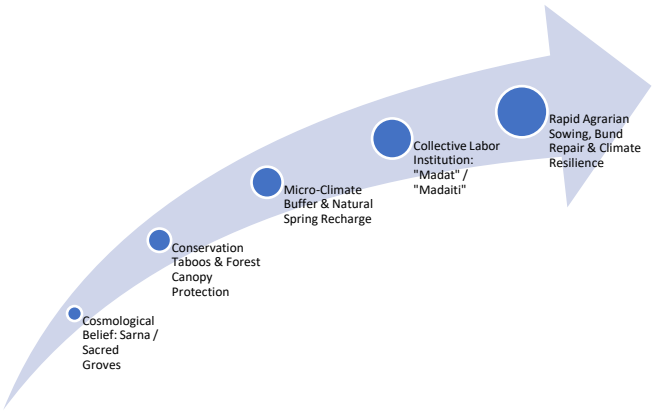
Community adaptation hinges on localized rainwater harvesting. Informants illustrated the reliance on small, earthen detention ponds (*dobhas*) dug into natural slope contours. These unlined reservoirs serve as micro-percolation pits that arrest runoff, recharge shallow open wells, and provide critical life-saving irrigation during terminal drought phases without requiring external energy inputs.

Theme 3: Institutional Governance: Sacred Groves (*Sarna*) and Mutual Aid (*Madat*)

Ecological adaptation is inseparable from the social and institutional fabric of the village. Resource regulation is sustained through cultural taboos and institutionalized mutual reciprocity.

Sacred Groves (*Sarna*) as Ecological Anchors

The *Sarna*, an untouched tract of mature climax forest maintained in each settlement, is governed through customary bans administered by the village priest (*Pahan*). Felling live trees, collecting timber for commerce, or grazing livestock within the *Sarna* is culturally forbidden. Ethnographic observations confirm that these groves function as micro-climatic moderators, soil stabilizers, and critical preservation sites for native pollinators and subterranean spring recharge (*Dari*).



Collective Labor Mechanisms (*Madat* / *Madaiti*)

Unpredictable rainfall compress the window available for field operations. When the monsoon arrives unexpectedly, single-family labor is insufficient to plow, puddle, and transplant seedlings before the topsoil moisture evaporates. Under the reciprocal institution of *Madat*, entire hamlets mobilize collectively to work the fields of vulnerable households (widows,

elders, and resource-poor families) in exchange for shared meals, bypassing cash constraints and mitigating seasonal climate vulnerability.

DISCUSSION AND POLICY IMPLICATIONS

Discussion

The empirical findings from this study demonstrate that Indigenous Ecological Knowledge (IEK) operating among the Munda and Oraon communities is neither an anachronistic cultural remnant nor an informal, inferior substitute for formal climatology. Rather, it functions as an autonomous, dynamic socio-ecological adaptation framework (Berkes, 2018). In regions characterized by high agro-climatic vulnerability, such as the Chota Nagpur Plateau, local livelihood security relies heavily on the synergy between ecological semiotics, agro-biodiversity, and collective institutional governance.

Epistemological Convergence: Ethno-Meteorology and Synoptic Science

The ethno-meteorological indicators identified, such as insect reproductive shifts and avian nesting stratigraphy, align with ecological observations regarding animal sensitivity to barometric pressure, micro-humidity fluctuations, and seasonal photoperiods (Reyes-García et al., 2016; Roncoli et al., 2002). While centralized meteorological forecasts provide probabilistic projections across macro-administrative grids (often at district or regional scales), they frequently fail to account for micro-topographical rain-shadow effects and localized soil-moisture variations. The bio-semiotic indicators employed by tribal farmers provide place-based, actionable foresight that guides granular field-level decisions, such as the exact day to broadcast seeds or trench drainage lines, bridging the temporal gap left by top-down weather advisories.

Agrobiodiversity as Ecological Insurance

The strategic cultivation of minor millets (*Eleusine coracana*, *Panicum sumatrense*) and drought-tolerant pulses across undulating topography exemplifies what Altieri et al. (2015) term "ecological redundancy." By diversifying crop portfolios across tiered elevations (*don* and *tanr* fields), tribal farmers decentralize operational risk. This strategy runs counter to the monocultural intensification models long promoted by Green Revolution interventions, which prioritized high-yielding varieties (HYVs) requiring uniform moisture regimes and capital-intensive irrigation. Within rain-fed tribal agrarian belts, the erosion of native landraces in favor of input-dependent commercial hybrids elevates economic vulnerability during prolonged dry spells, vindicating traditional polycultural systems as sustainable adaptation mechanisms.

Social Capital and Sacred Ecology as Resilience Buffers

Through the theoretical lens of Social-Ecological Resilience (Folke, 2006), customary institutions like the *Sarna* (sacred groves) and *Madat* (reciprocal labor mobilization) serve as structural pillars that prevent socio-ecological collapse. The conservation of sacred groves transcends spiritual symbolism; it preserves micro-watersheds, retains vital forest canopy cover, and safeguards native pollinator communities essential for rain-fed crops (Gadgil et al., 1993; Malhotra et al., 2001). Simultaneously, the institution of *Madat* buffers agrarian households against acute climate-induced labor bottlenecks. When monsoon onset fluctuates unpredictably, this collective solidarity bypasses financial liquidity constraints, illustrating that community resilience is fundamentally anchored in social capital.

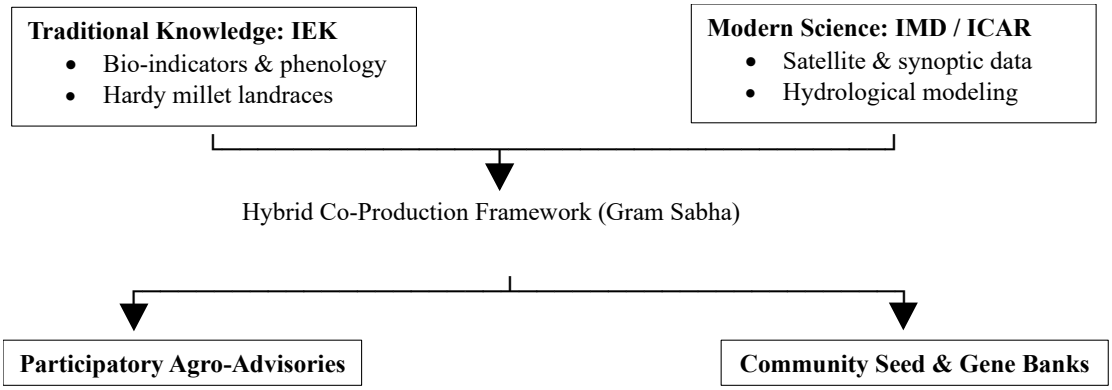
Vulnerabilities and Intergenerational Knowledge Erosion

Despite its structural utility, IEK faces systemic existential pressures:

- **Generational Disconnect:** Rapid out-migration of tribal youth toward urban informal labor sectors disrupts the oral transmission of ecological idioms and customary practices.
- **Institutional Secularization:** State-sponsored developmental programs often bypass traditional village authorities (*Pahans* and *Mundas*), eroding customary resource governance systems.
- **Climatic Threshold Exceedance:** Increasingly erratic climate shifts, such as unseasonal cloudbursts or multi-year extreme droughts, occasionally surpass the predictive accuracy of folk bio-indicators, creating emergent adaptation deficits.

Policy Implications

To transform these anthropological insights into actionable strategies, regional and national climate frameworks, including State Action Plans on Climate Change (SAPCC) and decentralized planning mechanisms, must move away from purely technocratic paradigms toward participatory co-production models.



1. Developing Hybrid Agro-Advisory Systems

Agricultural extension services and the India Meteorological Department (IMD) should integrate localized ethno-meteorological indicators with synoptic satellite forecasting. Establishing village-level hybrid weather advisories that validate and cross-reference folk indicators with digital forecasts enhances community trust and improves advisory adoption rates.

2. Decentralized In-Situ Seed Banking and Millet Revival

Government schemes under the National Millet Mission and state-specific tribal development initiatives must actively support *in-situ* community seed banks managed by local Self-Help Groups (SHGs). Protecting and distributing landrace germplasms (*Madua*, *Gondli*, native upland rice) reduces dependence on commercial hybrid seeds that demand high water and chemical inputs.

3. Institutional Recognition of Customary Water and Forest Systems

Rural employment schemes (such as MGNREGA) should realign micro-irrigation interventions with customary hydrological knowledge. Rather than constructing standardized concrete check-dams, investments should prioritize the restoration of traditional earthen retention ponds (*dobhas*) and contour-aligned drainage systems (*ahar-pyne* remnants) identified by traditional village elders.

4. Statutory Empowerment of Customary Environmental Custodians

Under the provisions of the Panchayats (Extension to Scheduled Areas) Act (PESA) and the Forest Rights Act (FRA), traditional ecological custodians (*Pahans*, *Mundas*, and village councils) should receive institutional representation in local climate adaptation planning committees. Formal recognition and legal protection of *Sarna* sites as community-conserved biodiversity heritage zones will safeguard critical micro-ecosystems from infrastructural encroachment.

CONCLUSION

This study underscores the role of Indigenous Ecological Knowledge as an adaptive socio-ecological system operating across India's tribal heartlands. For the Munda and Oraon communities, climate adaptation is neither an abstract scientific dilemma nor a passive acceptance of environmental degradation; it is an active, iterative dialogue with the natural environment. Through the careful interpretation of ecological semiotics, the preservation of resilient landraces, and the cultural safeguarding of community micro-watersheds, these communities have historically sustained ecological equilibrium under shifting environmental pressures.

The findings challenge the prevailing dichotomy between scientific expertise and folk wisdom, illustrating that indigenous observations provide granular, micro-topographical resolutions that centralized meteorological grids cannot replicate. However, the operational continuity of IEK is increasingly jeopardized by rapid outward migration, cultural homogenisation, and the onset of unprecedented climatic anomalies that test traditional predictive thresholds. Preserving this knowledge requires moving beyond extractive documentation toward structural validation. Institutional frameworks must move past technocratic biases and legally empower customary village institutions (*Gram Sabhas*, *Pahans*, and *Mundas*), integrate traditional agro-ecological wisdom into rural development policies, and ensure that indigenous populations are recognized not merely as vulnerable subjects of climate change, but as foundational architects of regional climate resilience.

Limitations and Future Research Directions

While this research provides deep contextual and qualitative insights into the Chota Nagpur Plateau, several limitations suggest fruitful avenues for future inquiry:

- **Geographical Scope:** The empirical field data was gathered across three specific blocks in Jharkhand; comparative studies across contrasting agro-ecological zones (e.g., arid plateaus of Central India vs. high-altitude Himalayan tribal belts) would illuminate how diverse bio-semiotic indicators adapt across distinct micro-climates.
- **Longitudinal Validation:** Future interdisciplinary research should combine qualitative ethnography with multi-year quantitative data, pairing long-term meteorological recordings with indigenous bio-indicator timelines to measure scientific-traditional predictive correlations over extended decadal shifts.

Gender-Differentiated Studies: While women's focus groups were incorporated, focused inquiries dedicated specifically to gendered divisions of wild food foraging, seed curation, and domestic water-management technologies would deepen the understanding of ecofeminist dimensions within tribal adaptation.

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