



An Integrative Theory of Dew Ecology: Reconstructing its Origins across Diverse Natural Landscapes

Sofyang Daeng Kelana*¹, Gatot Ciptadi², Aulanni'am³, Bagyo Yanuwiadi⁴, Pattasang⁵

¹ Doctor of Environmental science university of brawijaya, Malang, Indonesia

² Faculty of Animals Husbandry, University of Brawijaya, Malang, Indonesia

³ Department of Chemistry, University of Brawijaya, Malang, Indonesia

⁴ Department of Biology, University of Brawijaya, Malang, Indonesia

⁵ University Ibnu Sina, Indonesia

Corresponding Author: Sofyang Daeng: sofyangkelana@gmail.com

ARTICLE INFO

Keywords: Origin, Condensation, Plants, Soil, Dew

Received : 27 Marcj

Revised : 20 April

Accepted: 25 May

©2026 Kelana, Ciptadi, Aulanni'am, (s): This is an open-access article distributed under the terms of the

[Creative Commons Atribusi 4.0 Internasional](https://creativecommons.org/licenses/by/4.0/).



ABSTRACT

This study aims to reconstruct the theoretical framework of dew formation in natural ecosystems by classifying its origins into three ecological pathways: atmospheric, plant-based, and subterranean, rather than attributing it solely to atmospheric condensation. The method employed is systematic observation and theoretical reconstruction through analysis of physical and chemical processes at three interfaces: atmosphere, biosphere, and geosphere, supported by field validation using plastic barriers to capture vapor rising from the soil. The results identify three types of dew: atmospheric dew formed by nocturnal temperature differences, transpiration (biological) dew resulting from interactions between plant-emitted water vapor and CO₂, and telluric (ground) dew driven by continuous geothermal evaporation that later condenses at the surface. These findings show that dew is not a singular phenomenon but the result of synchronized interactions among air, plants, and soil. The novelty of this study lies in its tri-origin framework of dew formation, integrating atmospheric, biological, and geothermal processes, offering a new perspective in eco-hydrology and water resource management.

INTRODUCTION

Dew formation is a ubiquitous yet sophisticated hydrological phenomenon that serves as a vital non-rainfall water source (NRWS) for various ecosystems (Li et al., 2025). In arid and semi-arid regions, as well as specific micro-climates, dew provides the necessary moisture to maintain taxonomic diversity and soil stability (Kidron & Starinsky, 2019). Traditionally, the prevailing scientific consensus has simplified dew as a singular atmospheric process—the condensation of ambient water vapor onto cooled surfaces. However, this reductionist view overlooks the multi-dimensional origins of dew in wild environments. This study proposes a tri-pedal theoretical reconstruction of dew ecology, distinguishing between atmospheric, telluric (geogenic), and botanical pathways of formation (Wang et al., 2017).

The complexity of what we define as "Natural Dew" (or Pure Ontological Dew) lies in its diverse provenance. First, Atmospheric Dew is governed by nocturnal radiative cooling, where the surface temperature drops below the dew point (Trosseille et al., 2021). Second, and more significantly, this research highlights the role of Telluric Dew—a continuous 24-hour evaporative cycle driven by geothermal flux. Unlike atmospheric condensation, telluric dew originates from the earth's internal thermal energy, causing subterranean moisture to rise and condense at the soil-atmosphere interface under nocturnal conditions (Liu et al., 2019). Third, the study identifies Biological/Transpiration Dew, a hybrid process involving plant respiration and the nocturnal release of Carbon Dioxide (CO₂), which facilitates the formation of highly structured droplets on green foliage.

A critical gap in current hydro-ecological literature is the failure to distinguish these "Natural" forms from "Mixed Dew" (Zhong et al., 2018). As observed in this study, the introduction of exogenous factors, such as residual precipitation or anthropogenic disturbances, alters the physical symmetry and optical properties of the dew droplets. Pure natural dew exhibits unique optical mirage effects and precise spatial arrangements—often occupying specific niches on leaf margins—which are lost when contaminated by rain or human activity. Furthermore, empirical data suggests that anthropogenic presence late into the night (past 23:00) disrupts the micro-climatic equilibrium necessary for pristine dew crystallization, indicating a high sensitivity to environmental stressors (Urso et al., 2024).

The significance of this theoretical reconstruction extends beyond physical hydrology into the realm of ethno-medicine and human biometrics. In various indigenous Indonesian contexts, natural dew is utilized as a high-purity therapeutic agent. Traditional practices involving pedestrian contact with dew-laden grasses are believed to stimulate motor development in children and enhance visual acuity. From a biochemical perspective, the "distilled" nature of dew in unpolluted wild environments suggests potential for metabolic detoxification and dermatological health.

By integrating these socio-ecological dimensions with a reconstructed physical theory, this research provides a holistic framework for understanding dew not merely as a weather byproduct, but as a sophisticated biological and geothermal output essential for both environmental and human well-being.

METHODOLOGY

This study employs a qualitative-phenomenological design (Hossain et al., 2024), grounded in ontological and epistemological inquiries into the lived reality of dew ecology. The choice of phenomenology is necessitated by the transient and highly variable nature of dew, which—despite being a daily occurrence—exhibits non-linear patterns in volume, morphology, and optical refraction due to fluctuating environmental variables. This approach allows for a deep exploration of dew as a "natural phenomenon-in-itself," moving beyond classical physical metrics to reconstruct its theoretical origins through direct field immersion. By treating dew as a factual yet under-researched entity, this methodology captures the essence of its existence from midnight formation to morning dissipation, ensuring that the "sacrifice of time" and "persistence of observation" are translated into rigorous academic data.

To ensure a comprehensive understanding of dew origins, purposive sampling was applied across diverse ecological landscapes in Indonesia. The primary observation sites include the Riau Archipelago (Batam, Setokok, Rempang, Galang, and Galang Baru islands) to represent maritime-influenced dew, and the agricultural plains of South Sulawesi for comparative inland analysis. These sites were further categorized into three specific micro-environments: (1) open grasslands for observing high-clarity botanical and atmospheric dew; (2) arid, geologically disturbed hill-cuts to isolate telluric (ground-based) dew; and (3) dense canopy areas to study the interaction between plant transpiration and nocturnal condensation. These diverse terrains provide the necessary contrast to validate the tri-pedal theory of dew origin across varying soil and atmospheric conditions.

The primary data for this study are derived from "Naturalistic Observation" and "Visual Documentation" conducted daily during the critical hours of 00:00 to 07:00. This study utilizes non-systematic observation, allowing the researcher to remain flexible and responsive to the unpredictable optical mirages and morphological shifts of dew. Data were captured using high-resolution macro-photography and time-lapse videography to document the life cycle of droplets on various substrates, from vibrant foliage to inert surfaces. This visual evidence serves as a "chromatic record" of dew's interaction with solar angles and biotic factors, such as insects utilizing dew for hydration and hygiene, which constitutes a vital part of the dew-ecological discourse.

To ensure the validity and reliability of the qualitative findings, this study adheres to the criteria of trustworthiness as proposed by Lincoln and Guba, specifically focusing on "Prolonged Engagement" and "Persistent Observation" (Ketekunan Pengamatan). By utilizing all human senses—including instinctual and auditory cues in the field—the researcher ensures a constant and consistent interpretation of the data. The research involved an extended period of residency

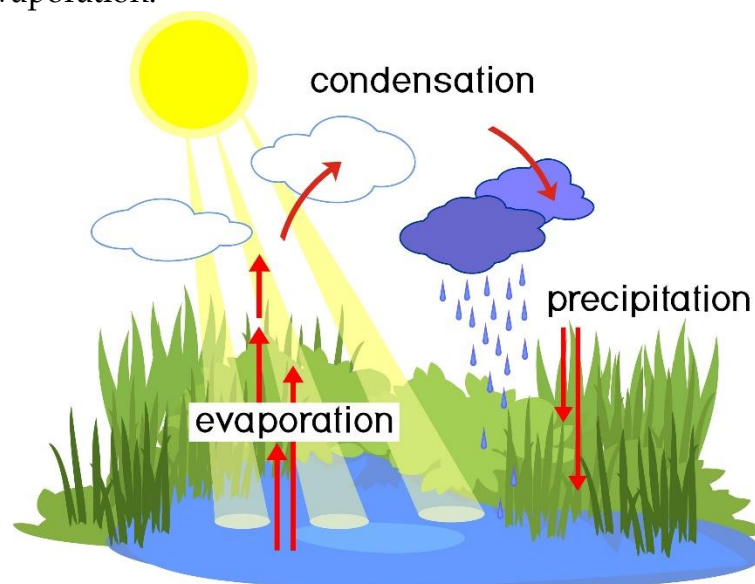
in the field, coupled with "Referential Adequacy" through the use of high-quality visual archives to confirm the stability of the observed phenomena. This rigorous immersion minimizes subjective bias and enhances the objectivity of the theoretical reconstruction (Alhazmi & Kaufmann, 2022).

Data were analyzed following the interactive model of Miles, Huberman, and Saldaña, comprising data collection, data reduction, data display, and conclusion drawing. The reduction process involved distilling thousands of visual frames and field notes into core thematic categories: Atmospheric, Telluric, and Biological. During "Data Display," the complex interactions between dew morphology and environmental stressors (such as anthropogenic disturbances before 23:00) were mapped into conceptual matrices and descriptive narratives. Final conclusions were reached through a "Constant Comparative" method, where field data were iteratively cross-referenced with existing eco-hydrological literature to ensure that the reconstructed theory provides a robust answer to the research questions.

RESEARCH RESULT

Results

The traditional paradigm in hydro-meteorology posits that dew is exclusively the product of atmospheric water vapor condensation driven by nocturnal radiative cooling. However, this study's longitudinal observations and experimental data reconstruct this theory into a tri-pedal model. We identify that dew in natural ecosystems originates from three distinct thermodynamic pathways: atmospheric condensation, botanical transpiration, and telluric (geogenic) evaporation.



1. Atmospheric Condensation: The Radiative Pathway

Atmospheric dew constitutes the most visually pristine category. It is formed when the surface temperature of objects in open environments drops below the dew point of the ambient air. Our observations through macro-photography reveal that this type of dew exhibits high optical clarity and diverse chromatic refraction ("mirage effects"). Unlike other forms, its distribution is

governed strictly by the thermal conductivity of the substrate and air-flow patterns, typically forming uniform, spherical droplets on non-living surfaces and horizontal planes.

2. Botanical Transpiration Dew: The Bio-Atmospheric Interface

A significant finding of this research is the characterization of dew formed through the interaction of plant physiology and the atmosphere. Unlike simple condensation, Botanical Dew is a result of nocturnal transpiration combined with the accumulation of Carbon Dioxide (CO₂) released by plants during respiration.

- Mechanism: The moisture emerges from the stomata and coalesces with ambient humidity, stabilized by the high concentration of CO₂ at the leaf interface.
- Morphology: Observations show a highly ordered spatial distribution on both the adaxial (top) and abaxial (bottom) surfaces of green leaves.
- Dissipation: This biological water source is transient; it either re-evaporates upon solar exposure or is mechanically redistributed into the soil through biotic interactions (human/animal contact) or precipitation.

3. Telluric Dew: The Geothermal Evaporative Cycle

The most novel contribution of this study is the empirical validation of Telluric Dew (Ground Dew). We hypothesize that this dew is the product of a continuous 24-hour evaporative cycle driven by the Earth's internal thermal flux.

Experimental Evidence: The Substrate Barrier Phenomenon

Initial qualitative evidence was gathered by observing clear plastic membranes placed over bare soil. The consistent accumulation of uniform water droplets on the underside of the plastic – isolated from atmospheric humidity – confirms that water vapor is being forced upward from the soil matrix.

Empirical Depth Analysis and Thermal Flux

To rigorously test the telluric hypothesis, a specialized "Dew Trap" system using 1500 ml cylindrical modules was deployed across various soil depths (0 cm to 40 cm) in arid, barren landscapes. Observation of Continuity: Across all 20 modules buried at intervals (e.g., 5, 15, 30, 40 cm), water vapor was successfully captured and condensed within the traps over a 24-hour period. Control Group Validation: Modules that were sealed at the bottom (preventing contact with the soil) showed zero accumulation, even when buried at identical depths. Thermodynamic Conclusion: These results prove that telluric dew is not a nocturnal-only event but a 24-hour geogenic process. During the day, this vapor escapes freely into the atmosphere; however, at night, the thermal gradient between the warm soil and the cooling surface facilitates its condensation into visible dew.

DISCUSSION

The findings of this study fundamentally challenge the traditional hydrometeorological paradigm, which for centuries has monolithically defined dew as a singular product of atmospheric vapor condensation triggered by nocturnal radiative cooling. The central argument proposed in this theoretical reconstruction is that dew in wild environments results from a synchronous interaction between three distinct physical domains: the atmosphere, the biosphere (plants), and the geosphere (soil). By introducing the "Tri-Pedal Origin" model, this research provides a novel resolution to the anomalies in dew distribution frequently observed in the field that cannot be explained solely by air temperature gradients. The novelty lies in the identification that dew is not merely a passive meteorological phenomenon but a dynamic output of biological metabolism and continuous terrestrial thermal flux. This shifts our understanding of the micro-hydrological cycle, wherein dew must now be viewed as a multifaceted entity with divergent formative ontologies depending on its environmental interface.

The Biological Imperative: CO₂-Stabilized Botanical Dew. The discourse on botanical or transpirational dew contributes significantly to the understanding of plant ecophysiology under nocturnal conditions. Contrary to the prevailing view that equates all water droplets on leaf surfaces with atmospheric condensation, our data argumentatively demonstrates a unique mixing mechanism between transpirational water vapor and the accumulation of carbon dioxide (CO₂) released by plants during nocturnal respiration. The physicochemical interaction between water molecules and CO₂ gas is hypothesized to act as a molecular stabilizer influencing surface tension, thereby creating highly organized dew morphology on both the adaxial and abaxial surfaces of leaves. This phenomenon proves that plants are not merely passive recipients of dew but active agents that construct their own hydration microclimates. The implications of these findings are extensive, particularly in understanding how vegetation in marginal regions or network-sparse environments maintains cellular vitality through internal moisture harvesting.

Telluric Dew and the Geothermal Evaporative Cycle. The most radical novelty of this study lies in the empirical validation of Telluric Dew, or geogenic dew, sourced from the Earth's thermal activity. Conventional arguments often overlook the role of internal terrestrial heat in surface dew formation; however, experiments utilizing plastic substrate barriers and cylindrical trap modules at depths of 0–40 cm demonstrate a soil evaporation flux that persists non-stop for 24 hours. This is a crucial finding that reshapes our understanding of "ground breathing," where water vapor from the pedosphere moves vertically upward due to geothermal heating. During the day, this vapor remains visually undetectable as it disperses freely into the open atmosphere; however, at night, as the surface interface cools, this telluric vapor is trapped and condensed before it can escape. The fact that control modules with sealed bottoms yielded zero water accumulation provides irrefutable evidence that the soil is an active and constant contributor to nocturnal surface water availability.

Morphological Distinction and the Optical Mirage Effect. Morphological analysis in this study provides a robust basis for distinguishing between "Natural Dew" (Pure Ontological Dew) and "Mixed Dew." We argue that the purity of the formation process—whether atmospheric, botanical, or telluric—produces unique physical characteristics, such as high optical clarity and the capacity to emit diverse optical mirages or chromatic refractions. Conversely, mixed dew contaminated by residual precipitation (rain) loses its structural symmetry and tends to wet surfaces irregularly. The significant difference in size, where natural dew tends to be more microscopic yet highly organized, indicates that natural formation processes involve a finer crystallization mechanism compared to rainwater droplets. This discovery is vital for the development of natural water quality sensors and can serve as a visual indicator to assess the hydrological purity of an ecosystem without requiring complex laboratory equipment.

Anthropogenic Sensitivity and Ecosystem Resilience. This research also highlights the ecological sensitivity of dew to anthropogenic disturbances, representing a new dimension in ecosystem resilience studies. Field observations indicate that intensive human activity leading up to midnight (23:00) significantly disrupts the stability of natural dew formation the following morning. This suggests that the natural condensation process requires a specific threshold of environmental tranquility and thermal equilibrium. The disruption of the dew cycle is not merely the loss of a visual phenomenon but a threat to the water availability for micro-organisms, such as insects and soil fauna, which rely entirely on dew for hydration and hygiene. Consequently, the conservation of dew ecosystems must be integrated into regional planning, particularly in rural areas, to safeguard the survival of small-scale biodiversity that plays a critical role in food chains and overall soil health.

Ethno-Science Integration and Holistic Health Implications. Integratively, this theoretical reconstruction bridges the gap between physical science and the local wisdom long practiced across various regions of Indonesia. The scientific explanation regarding the purity of telluric and botanical dew provides legitimacy for the use of dew as a traditional therapeutic agent, such as barefoot walking therapy for visual and motor recovery. Because natural dew is filtered through soil evaporation or cellular transpiration, it possesses a biochemical profile free from surface pollutants, making it a potent medicinal water source capable of supporting metabolic detoxification and dermatological health. This discussion concludes that recognizing the multifaceted origins of dew allows us to optimize this hydrological potential, not only for ecological balance but also as a sustainable and accessible public health resource in regions with limited access to clean water.

CONCLUSIONS AND RECOMMENDATIONS

This study successfully reconstructs the theory of dew origins through the Tri-Pedal Origin model, proving that dew in wild environments is not merely a passive product of atmospheric condensation. The fundamental findings reveal significant contributions from Telluric Dew (ground vapor), generated via a continuous 24-hour terrestrial thermal flux, and Botanical Dew, which is

stabilized by nocturnal CO₂ emissions. Empirical validation using trap modules at depths of 0–40 cm confirms that the soil acts as a constant hydration pump, while morphological analysis demonstrates that "Natural Dew" possesses unique optical clarity and structural symmetry that distinguishes it from mixed dew or residual precipitation. Implication: The implications of this research involve a theoretical repositioning within hydrometeorology and ecophysiology, where dew must now be viewed as a multifaceted Non-Rainfall Water Source (NRWS). Practically, the understanding of telluric and botanical dew purity provides scientific legitimacy for the use of dew in holistic health practices and ethnomedicine, while simultaneously offering new strategies for passive water harvesting in marginal regions. Furthermore, the sensitivity of dew to anthropogenic disturbances provides a new indicator for the conservation of micro-ecosystems that have historically been overlooked in environmental planning. Limitation: Although this study provides robust empirical evidence through a qualitative-phenomenological approach and field experiments, there are limitations regarding the depth of hydro-chemical analysis required to map the specific mineral content of each dew formation pathway. Additionally, data variability is highly dependent on the specific microclimatic conditions of the research sites (Riau Archipelago and South Sulawesi); thus, generalizing this theory to subtropical or polar climates may require adjustments to different thermal parameters.

ADVANCED RESEARCH

Future research should be directed toward quantitative water isotope analysis to trace the molecular signatures between soil vapor and plant transpiration with greater precision. There is also a need to develop Artificial Intelligence (AI) sensor instruments capable of automatically distinguishing dew types based on their refractive indices. Finally, further exploration into the pharmacological potential of isolated natural dew in wild environments could open new opportunities in biotechnology and sustainable natural medicine.

ACKNOWLEDGMENT

The authors express their deepest gratitude to the University of Brawijaya and University Ibnu Sina for providing the institutional support and academic environment necessary to conduct this interdisciplinary research. Special appreciation is extended to the mentors and co-authors from various departments whose scientific insights were instrumental in bridging the gap between phenomenology and environmental science. We also acknowledge the local communities in the Riau Archipelago and South Sulawesi for their hospitality and assistance during the rigorous field observations at dawn. Finally, this work is dedicated to all parties who supported the documentation of these transient natural phenomena as a vital source of ecological knowledge.

REFERENCES

- Alhazmi, A. A., & Kaufmann, A. (2022). Phenomenological qualitative methods applied to the analysis of cross-cultural experience in novel educational social contexts. *Frontiers in Psychology, 13*, 785134.
- Hossain, M. S., Alam, M. K., & Ali, M. S. (2024). Phenomenological approach in the qualitative study: Data collection and saturation. *ICRRD Quality Index Research Journal, 5*(2), 148–172.
- Kidron, G. J., & Starinsky, A. (2019). Measurements and ecological implications of non-rainfall water in desert ecosystems – A review. *Ecohydrology, 12*(6), e2121.
- Li, H., Han, C., Yang, Y., & Chen, R. (2025). Advances and Challenges in Dew Research on Land Surface: A Review. *Hydrology, 12*(12), 320.
- Liu, C., Wu, Y., Wang, B., Zhao, C. Y., & Bao, H. (2019). Effect of atmospheric water vapor on radiative cooling performance of different surfaces. *Solar Energy, 183*, 218–225.
- Trosseille, J., Mongruel, A., Royon, L., & Beysens, D. (2021). Radiative cooling for dew condensation. *International Journal of Heat and Mass Transfer, 172*, 121160.
- Urso, A., Velasco-Gómez, E., Tejero-González, A., Andrés-Chicote, M., & Nocera, F. (2024). Experimental study of the optimal design and performance of a mixed-flow dew-point indirect evaporative cooler. *Applied Thermal Engineering, 257*, 124294.
<https://doi.org/https://doi.org/10.1016/j.applthermaleng.2024.124294>

Wang, L., Kaseke, K. F., & Seely, M. K. (2017). Effects of non-rainfall water inputs on ecosystem functions. *Wiley Interdisciplinary Reviews: Water*, 4(1), e1179.

Zhong, Z., Liu, S., Kazemi, M., & Carr, T. R. (2018). *Dew Point Pressure Prediction Based on Mixed-Kernels-Function Support Vector Machine in Gas-Condensate Reservoir*. 1-16.