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Geoheritage, Local Wisdom, and Spring Conservation: The *Sedekah Sendang Dewot* Tradition of Wonosoco Village, Kudus Regency, Central Java, Indonesia

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Info Artikel

ABSTRACT

Riwayat:

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Spring-water resources worldwide are under mounting pressure from land-use conversion, urban expansion, and conservation models that rely heavily on top-down technical and regulatory instruments while neglecting the social, spiritual, and cultural dimensions of water stewardship. This study investigates how local wisdom contributes to evidence-based spring conservation through the case of *Sedekah Sendang Dewot*, an annual votive ceremony performed by the community of Wonosoco Village, Undaan District, Kudus Regency, Central Java, examined within the geoheritage framework of the Muria Mountain landscape. A mixed-methods design integrated quantitative spatial analysis using a Geographic Information System (GIS) with descriptive qualitative analysis, drawing on hydrogeological maps, a Digital Elevation Model, land-use/land-cover data, field-based geosite inventory, in-depth interviews, and participant observation. Results indicate that Sendang Dewot is a lowland spring, situated at approximately 21 metres above sea level, whose emergence is associated with a sub-surface hydrological system embedded in the volcanic landscape of Muria. The *Sedekah Sendang Dewot* tradition functions as a community-based conservation mechanism sustained through customary prohibitions, periodic ritual cleansing (*resik-resik*), and belief in a spiritual guardian (*danyang*) that reinforces compliance. Spatial zonation integrating hydrogeological and cultural criteria delineated a sacred core, hydrological buffer, education-and-culture zone, and landscape zone; overlay analysis showed that residential land use dominates all four zones, indicating persistent anthropogenic pressure even within the sacred core. These findings demonstrate that ritual-based local wisdom is a substantive, spatially expressed conservation instrument that can be systematically integrated with geoheritage science to inform sustainable, culturally grounded eco-geotourism planning in the Muria region.

Keywords: Community-Based Conservation; Eco-Geotourism; Geoheritage; Kudus Regency; Local Wisdom Spring Conservation.

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INTRODUCTION

The global water-resource crisis has intensified in recent decades, marked by widespread spring degradation, uncontrolled land conversion, and mounting urbanization pressure that significantly diminish the infiltration capacity and hydrological quality of landscapes worldwide (Bellini et al., 2025; Love et al., 2022). In earth-science terms, springs are no longer understood merely as a water commodity; they are increasingly recognized as integral components of hydrological *geoheritage* —

records of the geological, geomorphological, and aquifer dynamics that carry high scientific, ecological, and social value (Bellini et al., 2025). Yet conservation approaches long dominated by technical and structural solutions, such as physical infrastructure or top-down formal regulation, frequently fail to secure long-term sustainability because they underweight the social, spiritual, and cultural dimensions of the communities that depend on these resources (Hapsari et al., 2023; Setiawan & Wibowo, 2023). This shortfall has spurred the emergence of community-based conservation paradigms that position local communities as principal actors in resource governance, alongside a growing recognition of cultural ecosystem services — the symbolic and cultural values that function as pillars of environmental sustainability in their own right (Hapsari et al., 2023; Sulistyono & Sadiyah, 2023).

Geoheritage and Evidence-Based Spring Conservation

Untuk itu diperlukan adanya pernyataan kebaruan dari penelitian yang dilakukan yang diperkuat dengan kajian literatur dari penelitian terdahulu. Sumber *state of the art* dianjurkan dari sumber primer yaitu sumber referensi jurnal yang relevan dan publikasi terkini baik jurnal internasional maupun jurnal nasional.

Geoheritage, in Brilha's (2016) influential formulation, denotes the subset of geodiversity — the abiotic variety of rocks, landforms, soils, and hydrological features — whose scientific, educational, or scenic value justifies systematic inventory, assessment, and protection. Springs occupy a distinctive place within this framework: unlike static geomorphological features, they are dynamic expressions of subsurface aquifer behaviour, so that their conservation value is inseparable from the broader hydrogeological system that sustains them. This dynamic quality is precisely what exposes springs to compounding risk, since threats to any part of the recharge–flow–discharge continuum, from catchment deforestation to point-source contamination, can degrade the geoheritage value of the spring itself.

Contemporary geoheritage approaches to spring conservation increasingly integrate hydrogeological assessment, adaptive policy instruments, and data-driven monitoring to safeguard spring flow and associated ecosystems (Bellini et al., 2025). This framework has been applied across diverse global contexts, from adaptive water-allocation plans protecting artesian springs in Australia (Love et al., 2022) to regional-scale spring inventories that inform conservation decision-making (Bellini et al., 2025). In tourism settings, springs recognized as geoheritage remain vulnerable to anthropogenic pressure from rising visitor numbers, land conversion, and pollution, which requires calibrated impact management and visitor regulation (Bellini et al., 2025). The underlying premise of this literature — that scientific geoheritage assessment must be paired with governance mechanisms capable of translating evidence into durable protective action — resonates closely with Ostrom's (1990) classic argument that sustainable governance of common-pool resources depends on locally crafted institutions capable of monitoring use and enforcing rules, rather than on external administration alone.

Local Wisdom and Conservation: The Indonesian Case

In Indonesia, and on the island of Java in particular, community rituals such as *Nyadran* (an ancestral and spring-cleansing tradition observed across Central and East Java) and *Sedekah Sendang* (“votive offering to the spring,” a communal thanksgiving ceremony performed at a spring or water source) have proven to be effective community-based conservation mechanisms. Recent studies show that *Nyadran* functions not only as an expression of cultural identity but also as social capital that organizes collective maintenance and monitoring of water resources (Hapsari et al., 2023; Alfariy et al., 2021). Periodic ritual spring-cleansing (*resik-resik*) embedded in the *Nyadran* tradition has been documented across Semarang, Kendal, and Trenggalek, where local communities have built ritual-based water-management institutions capable of adapting to the pressures of climate change and urbanization (Nurhadi, 2023; Suciati, 2024; Lestari et al., 2025). The moral and religious framework attached to these practices reinforces behavioural norms that restrict destructive activity around springs, constituting a durable form of community-based conservation (Setiawan & Wibowo, 2023; Sulistyono &

Sadiyah, 2023). This body of work parallels Berkes's (2018) conception of traditional ecological knowledge as a “knowledge-practice-belief complex,” in which local ecological knowledge, resource-management practice, social institutions, and cosmology function together as an integrated conservation system rather than as isolated cultural artifacts.

***Sedekah Sendang Dewot* in Kudus: A Distinctive Local Setting**

Sedekah Sendang Dewot is an annual ritual performed in Wonosoco Village, Undaan District, Kudus Regency, Central Java, geographically situated within the Muria Mountain landscape. The tradition expresses a relationship of reciprocity between the local community and the spring, which is regarded simultaneously as a divine gift and a communal responsibility. Although ethnographic scholarship on *Sedekah Sendang* practices in general has expanded, documentation specific to *Sedekah Sendang Dewot* — particularly its geological, hydrological, and geoheritage characteristics — remains markedly limited in the scientific literature.

Research Gap and Objectives

Despite parallel advances in geoheritage science and local-wisdom scholarship, the two bodies of literature remain largely disconnected, revealing a significant interdisciplinary gap. International studies of spring conservation tend to privilege hydrogeological assessment and formal policy instruments (Love et al., 2022; Bellini et al., 2025), whereas Indonesian studies of local wisdom concentrate on socio-cultural dimensions and ritual practice without incorporating hydrogeological data or aquifer-vulnerability assessment (Hapsari et al., 2023; Alfariy et al., 2021). Empirical evaluation of the impact of cultural tourism on spring-water quality and biodiversity likewise remains scarce (Bellini et al., 2025), and while several studies have proposed integrating geological narratives with oral tradition to enhance the appeal of eco-geotourism (Bellini et al., 2025; Alfariy et al., 2021), a genuinely integrative approach that combines geoheritage assessment, ritual ethnography, and sustainable tourism design remains underdeveloped. In short, geoheritage science has yet to systematically absorb ritual-based local wisdom as an empirically observable conservation mechanism, and local-wisdom scholarship has yet to be grounded in spatial, hydrogeological evidence — a gap this study addresses directly by analysing *Sedekah Sendang Dewot* as a single, spatially and culturally integrated case.

Kudus Regency lies within the Muria Mountain landscape, whose geological and hydrological value is most visibly expressed in the springs that sustain community life. Land-use change and mounting economic pressure, however, threaten the long-term viability of these resources, underscoring the need for a conservation model that is rooted in local cultural values rather than technical instruments alone. This study accordingly (1) analyses the role of the *Sedekah Sendang Dewot* tradition as a local-wisdom practice in spring-water conservation, and (2) examines the geoheritage value embedded in Sendang Dewot as a basis for developing culturally grounded, sustainable eco-geotourism. In doing so, the study positions *Sedekah Sendang Dewot* not merely as a cultural practice but as part of a spatially and socially integrated geoheritage-based conservation system.

METHODS

This study employed a mixed-methods design combining quantitative spatial analysis through a Geographic Information System (GIS) with descriptive qualitative analysis. The approach was designed to produce an integrated picture of both the technical hydrogeological characteristics and the cultural values embedded within a single conservation and tourism-development framework. Data selection followed precedents in geotourism research that combine field inventory with remote-sensing layers (Insani et al., 2025; Haryono et al., 2022).

Four spatial datasets were used:

- Hydrogeological map, at a scale of 1:50,000 to 1:100,000, covering the Mount Muria area, used to identify geological units, aquifer types, and spring locations to support vulnerability classification and mapping (Rohaendi et al., 2022).

- Digital Elevation Model (DEM), used to derive the drainage network, slope gradient, and catchment-area delineation through digital geomorphometry (Insani et al., 2025).
- Land Use/Land Cover (LULC) data, sourced from Indonesia's Geospasial Information Agency (Badan Informasi Geospasial, BIG), used to map land cover for assessing contamination risk and visitor accessibility (Insani et al., 2025).
- Field inventory, comprising GPS point recording, photographic documentation, and geosite description to support geoheritage scoring (Haryono et al., 2022).

Qualitative data were obtained through two complementary techniques. In-depth interviews were conducted with customary leaders (*tokoh adat*), village elders, spring custodians, and members of the local community concerning the history, customary regulations, and meaning of the *Sedekah Sendang Dewot* tradition. Participant observation was carried out during the implementation of the *Sedekah Sendang* ritual itself, to record the physical conservation practices enacted by the community in real time.

Fieldwork adhered to standard ethnographic protocols for research at sacred sites: verbal informed consent was obtained from all interview participants, and observation during the ritual itself was conducted unobtrusively so as not to interfere with its proper performance. Given that *Sedekah Sendang Dewot* is simultaneously a religious ceremony and a research site, particular care was taken to ensure that documentation (photography and note-taking) respected moments and locations that community informants identified as especially sacred, most notably the area immediately surrounding the spring during the *resik-resik* cleansing and the placement of *sesaji* offerings.

Spatial analysis was undertaken to generate a buffer-based zonation of the area surrounding the spring, which was then integrated with land-use data through an overlay (clip) technique to identify environmental pressure and patterns of human interaction within each zone. Zone boundaries combined the regulatory sempadan (protection-buffer) standard under Indonesian law with a technical hydrogeological reference for inner protection zones (Fahriati et al., 2022), detailed further in Section 3.

The combination of spatial and qualitative techniques allowed hydrogeological evidence to be triangulated against ethnographic accounts of customary practice, addressing the interdisciplinary gap identified in Section 1. Quantitative outputs — spring coordinates, elevation, proximity to hydrological features, and land-use composition — were cross-checked against qualitative descriptions of ritual space (the location of offerings, the route of the ritual procession, and the boundaries of customarily protected vegetation) to ensure that the resulting zonation reflected both scientific and lived-cultural understandings of the site. This triangulation is consistent with recommendations in the geoconservation literature that geosite assessment be supplemented with community-derived spatial knowledge, particularly where site-specific scientific baseline data remain limited (Brilha, 2016).

RESULTS AND DISCUSSION

Hydrogeological and Spatial Setting of *Sendang Dewot*

Sendang Dewot is located in Wonosoco Village, Undaan District, Kudus Regency, at approximately 110.81006° E and -6.97250° S. Topographic analysis places the site at an elevation of approximately 21 metres above sea level, consistent with a lowland setting on relatively gently sloping terrain. Regionally, the site falls within the Muria Mountain landscape, dominated by volcanic rock formations produced by past volcanic activity (cf. Sutarto et al., 2023). Although situated in a lowland setting, the emergence of the spring at this location is inferred to be associated with a sub-surface hydrological system controlled by the juxtaposition of rock layers or fracture zones, allowing groundwater to reach the surface in the form of a *sendang* (spring pool). The nearest hydrological feature — a drainage channel or canal — lies approximately 504 metres from the spring, while other water sources are more distantly dispersed. In terms of land use, the immediate surroundings of the spring are dominated by residential settlement, with agricultural land situated approximately 3.06 kilometres away, indicating limited direct interaction between intensive agriculture and the spring. Distance to the nearest primary road (approximately 4.02 km) and to public facilities (approximately 5.24 km) indicates moderate-to-low accessibility, so that anthropogenic pressure in the immediate

surroundings remains comparatively limited; the site retains a relatively quiet environmental character, not yet subject to intense urban activity. These characteristics reinforce the interpretation of Sendang Dewot as a component of hydrological geoheritage formed through the interaction of geological processes and local aquifer dynamics.

This inference is broadly consistent with regional petrological evidence characterizing the Muria Volcanic Complex as a Quaternary volcanic system composed of interlayered lava, pyroclastic, and alkaline mafic units (Sutarto et al., 2023), a lithological arrangement that commonly generates the fractures and permeability contrasts through which perched or contact-spring systems emerge at the margins of volcanic edifices, even where the immediate surface expression is a low-relief plain rather than a mountain slope. Confirming this inference with certainty would require site-specific hydrogeological investigation — for instance, discharge monitoring or isotopic tracing — which lies beyond the scope of the present study and is proposed as a direction for future research in Section 5.

The existence of *Sendang Dewot* is closely bound to the social and cultural life of the surrounding community. This human-environment interaction is expressed in the cultural practices that have developed around the spring, most prominently in the *Sedekah Sendang Dewot* tradition as a form of local wisdom oriented toward safeguarding the sustainability of the water source.

Cultural Characteristics: The *Sedekah Sendang Dewot* Tradition

The *Sedekah Sendang Dewot* tradition is an annual ritual performed by the community of Wonosoco Village as an expression of gratitude intended to ensure that the spring remains clean, its water flow uninterrupted, harvests abundant, the community prosperous, and blessing and safety bestowed by God. Historically the ritual was held on *Jumat Wage* — a recurring date within the 35-day Javanese *pasaran* calendar — although its scheduling has since been adjusted to July. The sequence of activities begins with preparations undertaken chiefly by the men of the community, who gather around the spring to slaughter livestock, typically goats or water buffalo, as part of the ritual procession.

The meat produced from the slaughter is subsequently prepared for communal consumption, while specific parts — the head and feet — are set aside as *sesaji* (ritual offerings) placed at symbolically significant locations, including the spring itself and nearby crossroads. In the afternoon, community members reassemble, bringing food to perform a collective prayer as an act of *sedekah sumber* (“offering to the water source”). The sequence concludes with a communal meal that expresses shared values of solidarity and togetherness. The ritual series is further accompanied by traditional performing arts, notably *Wayang Klitik* (a flat, low-relief wooden shadow-puppet theatre, distinct from the leather *Wayang Kulit*), staged at two locations — around Sendang Dewot and Sendang Gading — with narratives adapted to the context of each site.

In the community’s perspective, water drawn from *Sendang Dewot* functions not only as a source of life but also carries symbolic and spiritual value; it is widely believed to possess healing properties and other benefits. More broadly, the *Sedekah Sumber* tradition embodies local-wisdom values reflecting a harmonious relationship between people and their environment. A set of unwritten rules is collectively upheld, including prohibitions on damaging or felling vegetation around the spring, obligations to maintain the cleanliness of the spring area, and periodic ritual cleansing (*resik-resik*) undertaken as part of ritual preparation.

Belief in the presence of a spiritual guardian (*danyang*) at the spring functions as a mechanism of social control that reinforces community compliance with these customary rules. The tradition therefore operates, indirectly but effectively, as a community-based conservation system that sustains the water resource through combined cultural and spiritual means.

Geoheritage-Based Zonation of *Sendang Dewot*

Based on the physical and cultural characteristics identified above, Sendang Dewot exhibits potential for limited, sustainable development as a geoheritage-based eco-geotourism destination. This potential rests not only on the spring’s status as hydrological geoheritage but also on the continuity of the *Sedekah Sendang Dewot* tradition, which carries educational, spiritual, and ecological value.

Zonation of the site requires reference to both formal regulatory standards and hydrogeological scholarship. Indonesian Government Regulation No. 38 of 2011 concerning Rivers (Republik Indonesia, 2011) stipulates a minimum spring-protection buffer (*sempadan*) of 200 metres radius from the spring's centre point as a strict form of physical protection, a provision reinforced by Regulation of the Minister of Public Works and Public Housing No. 28/PRT/M/2015 (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2015), which sets an identical 200-metre buffer for springs located outside forest areas. From a technical hydrogeological perspective, however, several studies indicate that the inner protection zone — intended to prevent direct contamination from domestic activity — can reasonably be set at a considerably smaller radius of approximately 15–50 metres from the spring source (Fahriati et al., 2022).

Table 1. Geoheritage–Cultural Zonation of the *Sendang Dewot* Area

Zone	Radius (approx.)	Primary Function	Role in the <i>Sedekah Sendang</i> Tradition	Prohibited Activities
Core Sacred Zone (Core Geo-Sacred)	0–15 m	Protection of the spring and core geological structure	Primary ritual centre; spring cleansing (<i>resik-resik</i>)	Permanent structures; paving/cementing of the spring rim; motorized vehicles
Hydrological Buffer Zone	15–200 m	Maintaining infiltration capacity and slope/embankment integrity	Ritual procession route and preparation area	Waste disposal; chemical fertilizer use; felling of protective trees
Education and Culture Zone	200–500 m	Geoheritage interpretation facilities and cultural stage	Venue for wayang and folk-art performances following the ritual	Extractive industry (mining); high-rise buildings obstructing the landscape view
Landscape (Geopark) Zone	> 500 m	Conservation of the mountain landscape (Kendeng–Muria)	Community plantation/forest area buffering the village ecosystem	Large-scale land conversion (dense settlement/factories)

Land-Use Pressure across Zones

Spatial overlay analysis (*clip*) between the *Sendang Dewot* zonation and land-use data shows that residential land use dominates every zone (Table 2). In the Core Sacred Zone — the area of highest sanctity — residential land use covers approximately 706.28 m² (≈ 0.07 ha), indicating that even the most sacred and strictly protected zone lies in close proximity to community dwellings. In the Hydrological Buffer Zone, residential coverage increases to approximately 2,607.42 m² (≈ 0.26 ha), reflecting more intensive interaction between human activity and the spring's protective zone.

In the Education and Culture Zone, residential land use reaches approximately 55,788.36 m² (≈ 5.58 ha), indicating that this zone constitutes the primary space of community activity and a strong candidate location for education- and culture-based tourism development. At the broader Landscape Zone scale, residential land use again dominates, covering approximately 104,413.84 m² (≈ 10.44 ha), reflecting that the wider environment surrounding *Sendang Dewot* is, in its entirety, situated within a settled landscape. This zonation pattern suggests that the local-wisdom-based approach aligns closely with the concept of modern geoheritage protection, in which scientific and cultural value are integrated within a single spatial-management framework.

Table 2. Residential (Built-Up) Land Use within Each Zone, Overlay Analysis Results

Zone	Residential Area (m ²)	Residential Area (ha)
Core Sacred Zone	±706.28	±0.07
Hydrological Buffer Zone	±2,607.42	±0.26
Education and Culture Zone	±55,788.36	±5.58
Landscape Zone	±104,413.84	±10.44

DISCUSSION

Local Wisdom as an Evidence-Compatible Geoconservation Mechanism

The findings reported above situate Sendang Dewot squarely within Brilha's (2016) conception of geoheritage as sites whose geological, geomorphological, and hydrological attributes carry scientific value that merits systematic inventory and protection. Yet unlike the geosites typically catalogued in the international literature — which are assessed primarily through scientific and touristic criteria — Sendang Dewot's protection has, in practice, been sustained for generations by a parallel, non-scientific system: customary prohibition, periodic ritual cleansing, and belief in a spiritual guardian. This finding extends Brilha's (2016) framework by demonstrating that geoconservation outcomes can emerge from culturally encoded governance operating independently of, yet functionally analogous to, formal protective instruments — echoing Ostrom's (1990) argument that durable resource governance need not originate in state regulation but can instead be generated endogenously by resource-dependent communities that possess the authority, legitimacy, and monitoring capacity to enforce their own rules.

Read through Berkes's (2018) framework of traditional ecological knowledge as an integrated “knowledge–practice–belief complex,” the *Sedekah Sendang Dewot* tradition exhibits all four constitutive layers: empirical knowledge of the spring's behaviour and seasonality; the practical resource-management technique of *resik-resik* cleansing; the social institution of unwritten customary rules restricting vegetation clearance and waste disposal; and the cosmological layer expressed through belief in the *danyang* guardian spirit. This multi-layered structure explains why the tradition functions as more than symbolic performance: each ritual element corresponds to an identifiable conservation practice, and the belief system supplies a compliance mechanism that formal regulation alone often fails to generate (Hapsari et al., 2023). The pattern mirrors findings from Nyadran traditions documented in Semarang, Kendal, and Trenggalek (Nurhadi, 2023; Suciati, 2024; Lestari et al., 2025) and from ritual-based spring protection at Lingsar, Lombok (Jupri, 2021), suggesting that ritual-anchored water governance is not an isolated Kudus phenomenon but a recurring institutional form across Indonesia's agrarian and volcanic landscapes — a cross-regional consistency that strengthens the case for treating it as a generalizable conservation instrument rather than a merely local curiosity.

Zonation as Spatial Integration of Scientific and Cultural Value

The zonation constructed in this study demonstrates that this ritual-cultural logic can be rendered spatially explicit and made legible to formal planning instruments. The correspondence between the ritual's own spatial practice — the sacred core where offerings are placed, the processional corridor, the performance space for Wayang Klitik — and the regulatory buffers established under Government Regulation No. 38/2011 and Ministerial Regulation No. 28/PRT/M/2015 (each prescribing a 200-metre sempadan) indicates that customary spatial ordering and statutory protection are not competing systems but largely convergent ones. At the same time, the finer-grained inner protection zone identified in the hydrogeological literature (15–50 metres; Fahriati et al., 2022) corresponds closely to the tightly restricted Core Sacred Zone (0–15 m) identified through ethnographic mapping, in which prohibitions on permanent construction, paving of the spring rim, and vehicular access are strictly enforced. This convergence between an independently derived hydrogeological standard and a long-standing ritual boundary is itself evidence that community practice has approximated scientifically defensible protection thresholds well before such thresholds were formally quantified — a finding with direct relevance to the interdisciplinary gap identified in Section 1, since it shows that hydrogeological

evidence and local wisdom are not merely compatible in principle but are, at Sendang Dewot, already empirically aligned in practice.

Anthropogenic Pressure and the Limits of Ritual Governance

Nonetheless, the overlay results complicate any romanticized reading of ritual governance as fully protective. The dominance of residential land use across all four zones — including the 706.28 m² of settlement recorded within the Core Sacred Zone itself — demonstrates that ritual authority coexists with, rather than excludes, significant anthropogenic presence. This pattern is consistent with the broader Indonesian experience of watershed and spring degradation, in which an estimated 4,400 of the country's roughly 42,000 watersheds have been classified as requiring urgent rehabilitation (Wahyuningrum et al., 2023), underscoring that even culturally protected water sources are not immune to the settlement pressure driving national-scale hydrological decline. Read charitably, the persistence of an intact spring within a fully residential landscape is itself notable: it suggests that ritual prohibition — rather than physical isolation — is doing much of the protective work, since spatial separation from human settlement, the mechanism typically relied upon in conventional buffer-zone regulation, is largely unavailable here. This reframes the conservation question: for geoheritage embedded in densely settled rural landscapes, the operative safeguard may need to be behavioural and institutional (customary rule enforcement) rather than purely spatial (distance-based exclusion), a possibility formal Indonesian spring-protection regulation does not yet explicitly accommodate.

Implications for Eco-Geotourism Development

These dynamics carry direct implications for eco-geotourism planning. Consistent with GIS-based geotourism potential assessments conducted elsewhere in Indonesia — including karst land-suitability analysis in the Citatah area of the Bandung Basin (Rohaendi et al., 2022), geosite and geotourism potential assessment in Sumbawa (Qodri et al., 2024), and geodiversity assessment for geopark designation at Menoreh Mountain (Reinhart et al., 2023) — the findings here indicate that tourism development at Sendang Dewot should be spatially differentiated rather than applied uniformly. Visitor activity should be excluded from the Core Sacred Zone, which functions as the primary conservation area, and instead concentrated within the Education and Culture Zone, where geological, hydrological, and local-wisdom narratives can be jointly interpreted for visitors, consistent with calls in the international literature to integrate geological narrative with oral tradition in eco-geotourism design (Bellini et al., 2025; Alfariy et al., 2021). The Hydrological Buffer Zone, in turn, should retain its transitional function of preserving infiltration capacity and slope integrity rather than being opened to visitor infrastructure. Approached this way, eco-geotourism at Sendang Dewot need not be oriented primarily toward maximizing visitation; it can instead function as an educational medium that strengthens community awareness of water conservation — provided that development is pursued cautiously, with conservation principle and cultural value treated as non-negotiable priorities rather than as constraints to be optimized away.

Toward an Integrated Geoheritage–Local Wisdom Conservation Model

Taken together, these findings support the central argument of this study: that geoheritage evidence and local ritual practice are most effective not as parallel, separately managed domains but as a single, mutually reinforcing conservation model. Hydrogeological assessment supplies the scientific vocabulary and quantitative thresholds (aquifer type, inner protection radius, catchment delineation) needed to defend a site's protection in formal planning processes, while ritual practice supplies the social enforcement mechanism, the intergenerational transmission of ecological knowledge, and the cultural legitimacy that formal regulation alone routinely fails to generate in rural Indonesian contexts. The interdisciplinary gap identified in Section 1 — between geoheritage studies that emphasize technical assessment and local-wisdom studies that emphasize socio-cultural meaning — is thus not merely a gap in the literature but a gap in conservation practice itself. Closing it, as this study attempts to do through integrated spatial-ethnographic analysis, offers a template that other geoheritage sites embedded in living ritual landscapes across Java and beyond could plausibly adapt.

Cultural Ecosystem Services and the Limits of Economic Valuation

The persistence of *Sedekah Sendang Dewot* despite considerable settlement pressure also illustrates the analytical value of the cultural ecosystem services framework (Hapsari et al., 2023; Sulisty & Sadiyah, 2023), which treats symbolic, spiritual, and identity-related benefits as legitimate ecosystem outputs rather than as externalities to be weighed against more readily quantified provisioning services such as irrigation water or drinking supply. Conventional cost–benefit approaches to spring management struggle to represent the value of a communal meal, a shared prayer, or belief in a guardian spirit, yet it is precisely these intangible outputs that appear to generate the behavioural compliance documented in this study. This suggests that geoheritage valuation frameworks, which have historically emphasized scientific and touristic criteria (Brilha, 2016), would benefit from formally incorporating a cultural ecosystem services dimension when the site in question is embedded within a living ritual practice — not as a subordinate addendum to scientific assessment, but as a co-equal criterion capable of independently justifying protection. At Sendang Dewot, it is arguably the cultural service, rather than the hydrogeological scarcity of the resource, that has done most of the protective work to date, given that the spring is neither remote nor difficult to access and would otherwise be a plausible candidate for encroachment.

CONCLUSION

This study set out to analyse how local wisdom, expressed through the *Sedekah Sendang Dewot* tradition, contributes to the conservation of spring-water resources when read through the lens of geoheritage. The evidence assembled here shows that Sendang Dewot is not merely a source of water but a component of hydrological geoheritage shaped by the interaction of geological processes and aquifer dynamics within the Muria Mountain landscape. Despite being situated amid substantial residential development — a condition reflected in the dominance of settlement land use across every zone examined, including the sacred core — the spring persists through a community-based conservation mechanism, the *Sedekah Sendang Dewot* tradition, that integrates ecological, social, and spiritual values within a single cultural practice.

The zonation constructed by integrating spatial and cultural analysis demonstrates that a division of space grounded in sacredness and ecological function is broadly consistent with the principles of modern geoconservation, and in several respects anticipates hydrogeologically derived protection thresholds. The persistence of residential land use across all zones underscores the indispensable role of community stewardship — rather than physical isolation alone — in sustaining the spring, and confirms that ritual governance and formal regulatory protection should be understood as complementary rather than competing instruments.

For conservation policy and spatial planning, these findings suggest that spring-protection regulation in Indonesia — currently expressed through uniform, distance-based sempadan requirements (Republik Indonesia, 2011; Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2015) — would benefit from formally recognizing customary zonation and ritual governance as legitimate, evidence-compatible conservation instruments, particularly at sites where settlement density precludes purely spatial buffering. Local government bodies, including Kudus Regency’s regional development planning agency, are well positioned to codify the Core Sacred Zone, Hydrological Buffer Zone, Education and Culture Zone, and Landscape Zone identified in this study into spatial planning instruments (RTRW/RDTR) that give the *Sedekah Sendang Dewot* tradition formal standing alongside technical hydrogeological protection, while channeling eco-geotourism development strictly into the outer education-and-culture zone.

This study is subject to several limitations. The hydrogeological interpretation relies on secondary map data at a regional scale (1:50,000–1:100,000) rather than site-specific bore-log or aquifer-testing data, so inferences about the spring’s sub-surface connectivity remain interpretive rather than confirmatory. The qualitative component, while grounded in direct interview and observation, reflects a single ritual cycle and a single village community, limiting generalizability to other *Sedekah Sendang* traditions in the wider Muria region. Water-quality and biodiversity indicators — identified in Section

1 as an underexamined dimension of geoheritage tourism impact — were also outside the scope of this study.

Future research should pursue site-specific hydrogeological investigation (e.g., discharge monitoring, tracer studies, or borehole data) to verify the aquifer connectivity inferred here, alongside systematic water-quality and biodiversity monitoring to evaluate the ecological impact of any eco-geotourism development. Comparative studies across multiple *Sedekah Sendang* and *Nyadran* sites in the Muria landscape and elsewhere in Java would further test whether the convergence between customary zonation and hydrogeological protection standards observed at Sendang Dewot reflects a broader regional pattern, strengthening the case for institutionalizing local wisdom within Indonesia's geoheritage conservation framework.

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