

Research paper

Participation Under Constraint: Governing Risk, Knowledge, and Authority in a UNESCO Global Geopark

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ABSTRACT

UNESCO Global Geoparks are promoted as governance spaces that integrate geoheritage conservation, education, and sustainable development through community engagement. However, participation in many geopark settings can remain procedurally visible while institutionally constrained, raising questions about how participation design shapes governance outcomes, especially in hazard-prone landscapes. This study conceptualizes participation as an institutional system rather than an engagement activity and examines how authority structures, communication practices, and knowledge hierarchies interact to influence governance and risk management. Using an in-depth qualitative case study of the Dieng Plateau UNESCO Global Geopark in Central Java, Indonesia, where persistent volcanic-geothermal hazards coincide with expanding energy development, the study analyzes interviews, observations, and documentary materials to examine participation under centralized authority and epistemic asymmetry. The findings show that participatory interfaces are widespread but uneven in decisional influence; risk communication is inconsistent across channels and periods of uncertainty; and local experiential knowledge is frequently acknowledged yet rarely translated into decision-relevant inputs. To advance theory, the paper introduces the Participatory Geopark System (PGS) as an analytical framework comprising interdependent components: authority structures, participation interfaces, communication-and-trust infrastructure, and epistemic integration mechanisms. The study reframes participation as institutional design, links participation constraints to risk-governance vulnerabilities, and offers a practical lens for evaluating epistemically inclusive collaboration under real-world constraints.

Keywords: UNESCO global geoparks, participatory governance, risk governance, epistemic justice, Indigenous knowledge, geothermal hazards

UNESCO Global Geoparks are territorially bounded governance spaces that integrate the protection of geological heritage, biodiversity conservation, and cultural heritage within broader strategies of education and sustainable development (Louis et al., 2025). Beyond their conservation mandate, geoparks are increasingly conceptualized as place-based governance arrangements that rely on cooperation among public authorities, local communities, and other stakeholders (Omosanya & Ridwan, 2025). Within this framework, participation is positioned as a foundational principle, reflecting the expectation that local populations, particularly Indigenous and long-settled communities, play an active role not only as beneficiaries but also as co-stewards of landscapes shaped by long-term human–environment interaction (Rodrigues et al., 2025). The Dieng Plateau in Central Java, Indonesia, exemplifies this integrated heritage landscape (Putranto et al., 2025). Characterized by active volcanic

and geothermal systems, the region also contains ninth-century Hindu temples and enduring cultural traditions practiced by the Wong Dieng community, whose livelihoods and knowledge systems are deeply embedded in the plateau's dynamic environment (Pudjoarinto & Cushing, 2001). Together, these geological, ecological, and cultural attributes have positioned Dieng as a site of international significance consistent with UNESCO Global Geopark objectives (Putranto et al., 2025). However, the governance arrangements through which these values are managed reveal persistent tensions between global principles of community-centred participation and nationally centralized decision-making structures.

In practice, authority within Dieng Geopark is concentrated within Indonesia's heritage administration, particularly the Cultural Heritage Preservation Agency (BPCB), where decision-making power largely rests with state officials rather than local residents (Suherlan & Hidayah, 2025). As a result, participation by the Wong Dieng community is often limited to consultative or symbolic roles, with little influence over strategic decisions related to land use, heritage management, or risk governance (Thanasack et al., 2026). This divergence between policy rhetoric and lived governance experience reflects what Arnstein (1969) famously described as tokenism, forms of participation that create the appearance of inclusion without transferring meaningful decision authority. Empirical analyses of Dieng confirm a growing gap between institutional objectives and the recognition of local voices, values, and visions in governance processes (Suherlan & Hidayah, 2025). These participation deficits carry consequences that extend beyond questions of legitimacy or fairness. Dieng is a persistently hazardous volcanic–geothermal landscape, internationally documented for lethal volcanic gas emissions and environmental uncertainty (Diliberto et al., 2021). The 1979 Sinila Crater disaster, caused by a sudden release of carbon dioxide-rich gases, remains one of the most severe volcanic gas fatality events recorded worldwide and continues to shape risk perceptions among local residents (Malik et al., 2023). Contemporary hazards, including geothermal pipe leaks, soil degradation, and pollution associated with energy infrastructure, remain embedded within everyday life in the plateau (Sambodo et al., 2021).

Research in disaster risk governance consistently demonstrates that risk is not solely a technical phenomenon but is socially produced through governance structures, power relations, and communication practices (Hermans et al., 2022). Where participation is weakly institutionalized, communities may be exposed to hazards without access to decision-making channels that enable prevention, preparedness, or accountability. In Dieng, the absence of joint planning mechanisms and emergency coordination has contributed to chronic anxiety, contested land acquisition processes, and perceptions of unequal compensation linked to geothermal expansion (Chuwa & Perfect-Mrema, 2025). In such contexts, technical hazards become intertwined with social, political, and security concerns, directly undermining community well-being and the core objectives of geopark governance (Pashentsev & Kolotaev, 2025; Tang et al., 2025). A further governance challenge concerns the treatment of Indigenous and local experiential knowledge. Across hazard-prone environments, evidence shows that long-term, place-based knowledge can enhance the interpretability, credibility, and effectiveness of risk communication and preparedness strategies (Vasileiou et al., 2022). Yet, institutional decision-making systems frequently privilege standardized, expert-driven forms of knowledge, marginalizing local observations and interpretations through epistemological hierarchies (Gosselin & Gauquelin, 2025; Hermans et al., 2022). In geopark contexts, where community-centred narratives are central to institutional identity, such epistemic exclusions weaken trust and encourage reliance on informal information networks operating outside formal governance structures (Eze & Siegmund, 2024).

Despite these stakes, geopark scholarship has largely focused on geosite inventories, geotourism development, and educational initiatives, with comparatively limited analytical attention to participation as an institutionalized governance system (Ferreira & Valdati, 2023). Where participation is examined, it is often treated as observable activity, meetings, consultations, or benefit-sharing, rather than as a configuration of authority, accountability, and decision rights embedded within governance arrangements (Louis et al., 2025; Rodrigues et al., 2025). Governance research cautions that participation does not automatically yield collaborative outcomes unless supported by formal authority-sharing mechanisms, clear accountability structures, and sustained interaction among actors (Ansell & Gash, 2008). In hazard-prone settings, procedural inclusion without decisional power can have material consequences for safety, preparedness, and institutional credibility (Hermans et al., 2022). Arnstein's ladder remains a valuable diagnostic tool for identifying degrees of participation and tokenism; however, its linear and state-centric design does not fully capture the multi-actor, multi-scalar governance configurations characteristic of contemporary geoparks (Arnstein, 1969; Chuwa & Perfect-Mrema, 2025). As a result, existing frameworks often stop at critique, offering limited guidance for designing culturally grounded, actionable participation mechanisms capable of operating within centralized governance constraints.

To address this gap, this study develops an integrative governance model grounded in the Dieng Plateau case. Building on Arnstein's evaluative insights, collaborative governance theory, and Indigenous knowledge perspectives, the study advances the concept of a Geopark Participatory Ecosystem, an open, adaptive system that recognizes local communities as knowledge holders, governance actors, and co-producers of risk-relevant decisions (Chuwa & Perfect-Mrema, 2025; Surati et al., 2025). Through qualitative case analysis, the study examines: (1) how

top-down governance structures constrain meaningful participation by the Wong Dieng community; (2) the social, political, and risk-related consequences of participation deficits; and (3) the institutional mechanisms through which culturally respectful, decision-relevant participation can be strengthened. By doing so, the study contributes to geopark governance scholarship by reframing participation as governance design rather than engagement activity, advances disaster risk governance research by linking participation structures to trust and preparedness and offers a theoretically grounded yet practical model for shared decision-making in hazard-prone heritage landscapes. The findings culminate in the proposal of a Dieng Multi-Stakeholder Council (DMSC), operationalizing the Geopark Participatory Ecosystem through structured authority-sharing and knowledge integration (Sánchez-Cortez et al., 2025; Simbaña-Tasiguano et al., 2025; Souza et al., 2024).

LITERATURE REVIEW AND THEORETICAL FRAMING

Governance and participation in UNESCO Global Geoparks

Since their formal integration into UNESCO's International Geoscience and Geoparks Programme, UNESCO Global Geoparks (UGGPs) have increasingly been framed not merely as conservation or geotourism initiatives, but as territorially embedded governance instruments (Eze & Siegmund, 2024). Contemporary geopark scholarship emphasizes their role as platforms where geological conservation, education, cultural heritage, and sustainable development are coordinated through multi-actor collaboration (Ferreira & Valdati, 2023; Louis et al., 2025). Central to this framing is the normative expectation that local communities, particularly Indigenous and long-established populations, are not passive beneficiaries of geopark designation but active participants in shaping management priorities and development trajectories. Despite this normative emphasis, empirical research over the past decade reveals a persistent gap between participatory ideals and governance realities (Souza et al., 2024). Systematic reviews indicate that much geopark research continues to prioritize geosite inventories, geoeducation initiatives, and tourism product development, while governance structures, power relations, and decision-making authority remain under-examined (Ferreira & Valdati, 2023). Where participation is addressed, it is commonly operationalized through stakeholder satisfaction, perceived benefits, or attitudes toward geopark initiatives rather than through institutional analysis of who holds authority, how decisions are made, and how accountability is enforced (Louis et al., 2025).

This pattern has produced what may be described as a participation–authority gap, wherein participation is highly visible as activity, meetings, consultations, advisory councils, but remains analytically opaque as a mechanism of governance. Recent empirical studies underscore this concern. Rodrigues et al. (2025) demonstrate that while geoparks increasingly function as spaces for science communication and public engagement, participatory arrangements remain heterogeneous and rarely institutionalized as co-decision mechanisms. Similarly, comparative analyses of geoparks in Asia and Europe show that community participation frequently takes place through consultative forums, while strategic decisions remain centralized within governmental or expert-led institutions (Simbaña-Tasiguano et al., 2025). Crucially, existing geopark governance research tends to frame participation deficits primarily as problems of legitimacy, inclusion, or development effectiveness (Hutabarat, 2023). Much less attention has been paid to the functional consequences of participation design, particularly in geoparks located within environmentally volatile or hazard-prone landscapes (Sánchez-Cortez et al., 2025; Souza et al., 2024). This omission becomes especially consequential when governance arrangements shape not only social outcomes, but also environmental risk management, preparedness, and institutional trust.

Geoparks, environmental hazards, and risk governance

UNESCO Global Geoparks are explicitly expected to promote public understanding of geohazards and contribute to disaster risk reduction through education, awareness-raising, and community engagement (Bortolotto, 2024). Yet, empirical research connecting geopark governance structures to risk governance outcomes remains limited and fragmented. Studies across UNESCO-designated heritage contexts indicate that disaster preparedness and risk response depend less on technical monitoring capacity alone and more on governance quality, institutional coordination, communication credibility, and trust between authorities and communities (Eze & Siegmund, 2024). Within geopark scholarship, hazards are frequently treated as contextual background rather than as governance challenges shaped by institutional arrangements (Sánchez-Cortez et al., 2025). This contrasts sharply with disaster risk reduction (DRR) literature, which emphasizes that risk is socially produced through governance structures, power relations, and communication practices rather than being a purely technical phenomenon (Hermans et al., 2022; Maurischa et al., 2023). Where participation is weakly institutionalized, communities may be exposed to hazards without meaningful influence over prevention strategies, preparedness planning, or emergency response decisions.

Emerging studies begin to hint at this connection. Kabisch et al. (2016) show that community knowledge can meaningfully inform nature-based solutions in hazard-exposed geopark settings, but they also identify persistent coordination failures and uneven inclusion. However, geopark research has rarely examined how participation design itself influences risk communication credibility, early warning legitimacy, or the circulation of locally grounded hazard knowledge. As a result, a critical theoretical gap persists between geopark governance scholarship and risk governance research (Zhuang et al., 2024). This gap is particularly salient in geoparks embedded within development-intensive and hazard-regulated landscapes, where infrastructure projects, environmental uncertainty, and regulatory constraints intersect. In such contexts, participation design influences not only perceptions of fairness but also how uncertainty is interpreted, how warnings are trusted, and how communities respond during hazardous events (Hermans et al., 2022). Yet these dynamics remain insufficiently theorized within geopark studies.

Arnstein's ladder and the limits of hierarchical participation models

Arnstein (1969) Ladder of Citizen Participation remains one of the most influential frameworks for diagnosing power asymmetries in participatory processes. Its enduring relevance lies in its capacity to distinguish between forms of non-participation, tokenism, and genuine power sharing. In heritage and conservation contexts, Arnstein's ladder has been widely used to reveal how consultation-heavy processes may coexist with centralized authority, resulting in procedural inclusion without decisional power (Giraud-Labalte et al.; Routh et al., 2025). Applied to geopark governance, Arnstein's framework is particularly effective in identifying symbolic participation, where communities are invited to advise or provide feedback but lack influence over strategic outcomes. Empirical studies demonstrate that many geoparks operate at the levels of consultation or placation, with advisory councils and community representatives incorporated without authority transfer (Louis et al., 2025). Such arrangements preserve existing power structures while creating the appearance of inclusivity. However, Arnstein's ladder also exhibits important limitations. Its linear and hierarchical structure assumes that participation necessarily progresses toward full citizen control as an ideal endpoint, a normative assumption that is often infeasible in hazard-regulated or infrastructure-intensive contexts (Hanan & Carhart, 2025). Moreover, the framework offers limited guidance on how participation can be redesigned within centralized governance systems or how hybrid forms of shared authority might function in practice (Sharma, 2025). As a result, Arnstein's ladder is diagnostically powerful but analytically insufficient for explaining how participation operates within complex, multi-actor governance environments such as geoparks.

Collaborative governance as an institutional lens

To move beyond descriptive accounts of participation, this study adopts collaborative governance as its primary analytical framework. Collaborative governance scholarship conceptualizes participation not as an abstract democratic ideal but as an institutional arrangement in which public agencies and non-state actors engage in sustained, structured interaction to jointly influence policy or management outcomes (Ansell & Gash, 2008). Subsequent syntheses emphasize that effective collaboration depends on specific design conditions, including the distribution of decision authority, communication reliability, accountability mechanisms, and the management of power asymmetries (Aivalli et al., 2025). Importantly, collaborative governance research cautions against assuming that participation automatically produces collaboration. Participation must be institutionally enabled and continuously maintained; otherwise, participatory forums risk generating frustration, eroding trust, and reinforcing existing hierarchies (Fung, 2015). In geopark contexts, collaborative governance offers two key analytical advantages. First, it shifts attention from participation as presence to participation as decision influence, enabling systematic examination of who can shape outcomes and under what conditions (Nuh et al., 2024). Second, it accommodates multi-level governance complexity, recognizing that geoparks often operate across local, regional, and national institutional scales (Zhuang et al., 2024). Within this framing, Arnstein's ladder is retained as a diagnostic tool but embedded within a broader institutional analysis. Rather than treating participation as a linear progression, collaborative governance allows for partial, hybrid, and constrained forms of shared decision-making that reflect feasibility conditions in hazard-regulated environments.

Indigenous knowledge, epistemic justice, and decision relevance

A further limitation of geopark governance research lies in its treatment of Indigenous and local knowledge. While policy discourse frequently emphasizes the value of traditional knowledge systems, empirical studies demonstrate that such knowledge is often incorporated symbolically or instrumentally rather than as a basis for shared decision-making (Vasileiou et al., 2022). Disaster risk reduction research provides robust evidence that integrating local and scientific knowledge enhances relevance, legitimacy, and responsiveness, yet also shows that integration is structurally difficult due to epistemological differences and institutional power asymmetries (Hermans et al., 2022). These challenges are increasingly conceptualized through the lens of epistemic justice,

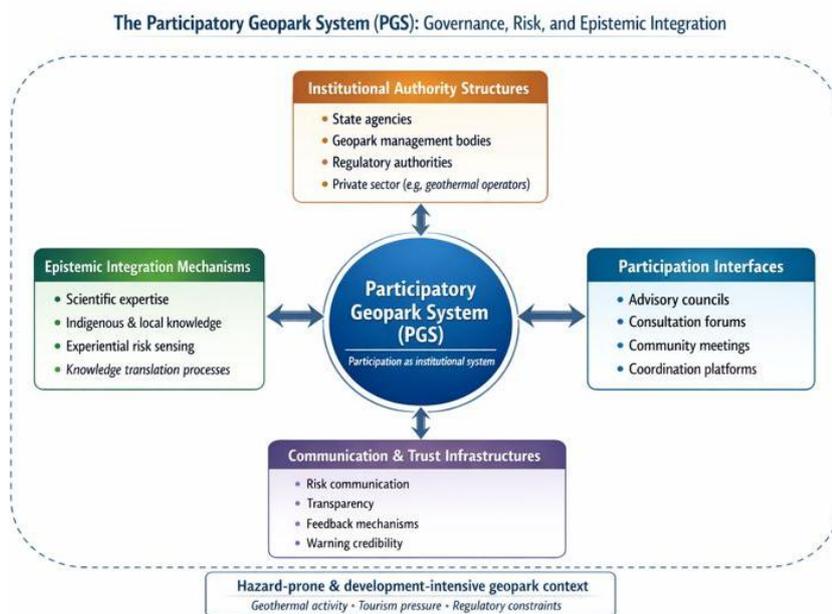
which foregrounds whose knowledge is recognized as legitimate within governance systems (Fricker, 2007; Whyte, 2020). In hazard-prone environments, epistemic injustice is not merely an ethical concern; it has practical consequences for how risks are interpreted, how warnings are trusted, and how communities respond to official guidance (Gosselin & Gauquelin, 2025). Yet geopark scholarship has rarely theorized epistemic justice as a governance mechanism, instead treating local knowledge as cultural enrichment or educational content.

Synthesis and conceptual framework: The participatory Geopark System (PGS)

Taken together, the literature reveals three interrelated gaps. First, participation in UNESCO Global Geoparks is rarely examined as an institutional design problem concerned with authority distribution, accountability, and influence. Second, the functional implications of participation design for risk governance in hazard-prone geoparks remain under-theorized. Third, the epistemic conditions under which Indigenous and local knowledge becomes decision-relevant rather than symbolically acknowledged are seldom analyzed. To address these gaps, this study integrates collaborative governance, risk governance, and epistemic justice perspectives to develop the Participatory Geopark System (PGS) (Figure 1). While Arnstein's ladder remains a powerful diagnostic tool for identifying tokenism and power asymmetries, its analytical scope is limited by its linear and normative structure. The Participatory Geopark System (PGS) extends Arnstein's insight by reframing participation not as a hierarchical progression toward full citizen control, but as an institutional system shaped by interacting authority structures, communication practices, and epistemic integration mechanisms. Rather than asking where participation is located on a ladder, the PGS examines how participation operates under feasibility constraints, how decisional influence is distributed across institutional components, and how participation affects governance outcomes in practice. In this sense, Arnstein's ladder functions as a critical point of departure, while the PGS provides an explanatory framework capable of analysing hybrid, partial, and constrained forms of participation characteristic of hazard-regulated geopark contexts. Additionally, the PGS conceptualizes participation as an interdependent institutional system composed of four interacting components: (1) institutional authority structures, (2) participation interfaces, (3) communication and trust infrastructure, and (4) epistemic integration mechanisms. Rather than proposing a prescriptive or idealized governance model, the PGS functions as an analytical heuristic for diagnosing where participatory claims outpace institutional realities and where feasible adjustments may improve governance performance in hazard-prone geopark contexts.

Figure 1

The participatory geopark system (PGS): Participation as an institutional system in hazard-prone geopark governance



METHODOLOGY

Research design and epistemological orientation

This study adopts a qualitative case study research design to examine how participation operates as an institutional system within a hazard-prone geopark context. Qualitative case studies are particularly appropriate for investigating complex governance phenomena where institutional arrangements, power relations, and knowledge

dynamics are deeply embedded within specific social and environmental settings (Yin, 2018). In contrast to variable-oriented approaches, case study research enables in-depth exploration of how governance processes unfold in practice, capturing interactions among actors, institutions, and contextual conditions that are difficult to isolate quantitatively (Flyvbjerg, 2004). The study follows an interpretive epistemological orientation, recognizing that governance, risk, and participation are socially constructed through meaning-making, communication practices, and institutional norms (Schwartz-Shea & Yanow, 2013). This orientation is consistent with disaster risk governance research, which emphasizes that perceptions of risk, legitimacy, and trust are shaped by social interpretation rather than by technical assessments alone (Renn, 2017). Rather than seeking causal generalization, the study aims for analytical generalization by developing theoretically grounded insights that can inform understanding of similar governance contexts (Yin, 2018). The Participatory Geopark System (PGS) is used as a sensitizing framework rather than as a prescriptive or deductive model. Sensitizing concepts provides interpretive guidance while allowing empirical patterns to emerge inductively from the data (Lim, 2025). This approach is particularly appropriate given the study's aim to examine participation under constraint, without imposing assumptions of ideal collaboration or full power devolution.

Case selection: Dieng plateau UNESCO global geopark

The Dieng Plateau UNESCO Global Geopark in Central Java, Indonesia, was selected as a critical and information-rich case based on three criteria commonly used in qualitative case selection: relevance, revelatory potential, and theoretical significance (Flyvbjerg, 2006). First, Dieng is a geopark landscape characterized by persistent volcanic–geothermal hazards, including documented lethal carbon dioxide gas emissions, making risk governance a central and ongoing concern (Sumotarto et al., 2023). Second, the geopark is embedded within a broader context of geothermal energy development, positioning it at the intersection of heritage governance, hazard management, and infrastructure development (Gong et al., 2021). Third, the area is inhabited by long-established local communities whose environmental observations and historical experience constitute a form of situated knowledge relevant to risk interpretation and preparedness (Mercer et al., 2010). From a governance perspective, Dieng represents a setting where participatory expectations articulated in UNESCO geopark policy coexist with centralized authority structures associated with hazard regulation and energy governance. This configuration makes Dieng particularly suitable for examining how participation is institutionally configured under feasibility constraints, rather than in contexts where decentralization is already advanced (Newig & Koontz, 2014). Accordingly, the case allows for theory building around participation design in geoparks characterized by high risk, regulatory complexity, and epistemic asymmetry.

Data collection methods

Data were collected using multiple qualitative sources to enable triangulation and enhance analytical credibility (Denzin, 2012). Fieldwork was conducted across multiple visits between 2019 and 2024, enabling iterative engagement with the field and sensitivity to evolving governance arrangements and risk conditions. This extended temporal scope allowed the research team to observe changes in participation practices, communication strategies, and institutional responses over time, rather than relying on a single snapshot of governance dynamics.

Semi-structured interviews

Semi-structured interviews constituted the primary data source. This method is well-suited to governance research because it allows participants to articulate experiences, interpretations, and concerns in their own terms while ensuring coverage of key analytical themes (Kvale, 2009). Interview participants were selected through purposive sampling to capture perspectives across governance levels and institutional roles (Masefield et al., 2020). Participants included: representatives of geopark management bodies and local government institutions; officials from environmental, disaster management, and regulatory agencies; representatives of private-sector actors involved in geothermal development; and community members, including local leaders and long-term residents with direct experience of hazard events. The interview guide focused on four thematic areas: participation and decision-making processes, distribution of authority, risk communication practices, and treatment of local or experiential knowledge in governance. Interviews typically lasted between 45 and 90 minutes and were conducted in settings chosen by participants to ensure comfort and confidentiality. All interviews were audio-recorded with consent and transcribed verbatim for analysis.

Observations and informal interactions

Non-participant observation was used to contextualize interview data and to capture interactional dynamics that may not be fully articulated in interviews (Chand, 2025). Observations were conducted during public meetings, consultation forums, and geopark-related events where access was permitted. Attention was paid to who spoke,

who was invited to speak, how risk information was presented, and how uncertainty was addressed. Informal conversations before and after meetings were treated as contextual data rather than as primary evidence, helping to interpret formal statements and identify discrepancies between official narratives and lived experience. Field notes were recorded systematically and included reflexive commentary on the researcher's positionality and access.

Document analysis

Document analysis complemented interview and observational data by providing insight into formal governance arrangements and official representations of participation and risk (Wehn et al., 2015). Documents included geopark management plans, policy guidelines, regulatory frameworks, meeting minutes, public communication materials, and environmental or risk-related reports. These materials were analyzed to identify stated participation mechanisms, institutional responsibilities, and narratives surrounding hazard management and development.

Data analysis

Data analysis followed a thematic analysis approach that combined inductive coding with theoretically informed interpretation (Braun & Clarke, 2006). Analysis proceeded in several stages. First, interview transcripts, observation notes, and documents were read iteratively to identify recurring patterns related to participation, authority, communication, and knowledge use. Open coding was used to remain close to the participants' language and meanings. In the second stage, codes were grouped into broader analytical themes aligned with the four components of the Participatory Geopark System: authority structures, participation interfaces, communication-and-trust infrastructure, and epistemic integration mechanisms. Importantly, this mapping occurred after inductive coding to avoid forcing data into predefined categories (Zhuang et al., 2024). Throughout the analysis, attention was paid to divergence and contradiction across stakeholder groups. Rather than seeking convergence, conflicting accounts were treated as analytically meaningful, reflecting contested governance processes and power asymmetries (Schwartz-Shea & Yanow, 2013). Analytical memos were used to document interpretive decisions and emerging insights.

Reflexivity and epistemic ethics

Reflexivity was treated as a core methodological requirement given the study's focus on participation and epistemic justice. Governance research acknowledges that researchers are embedded within power-laden contexts and that positionality can shape access, interpretation, and representation (Huygens & Gruber, 2025). The research team, therefore, remained attentive to how institutional affiliations, language, and cultural context influenced data generation. Interviews were conducted in languages preferred by participants, with careful translation to preserve meaning rather than literal phrasing. Particular attention was paid to culturally embedded expressions related to risk, responsibility, and authority. In line with ethical guidance on research with local and Indigenous knowledge, such knowledge was analyzed as situated expertise rather than as anecdotal or symbolic input (Whyte, 2020).

Trustworthiness and limitations

To enhance trustworthiness, the study employed data triangulation, transparent documentation of analytical procedures, and reflexive engagement throughout the research process (Ahmed, 2024). While the findings are not statistically generalizable, the study aims for analytical transferability by grounding insights in established governance and DRR theory. As a single-case study, the research is context-specific. However, the governance dynamics examined, centralized authority, hazard exposure, and epistemic asymmetry, are common across many geoparks and heritage governance settings. These limitations are acknowledged and revisited in the concluding section.

FINDINGS

The findings are structured around the four interdependent components of the Participatory Geopark System (PGS): (1) institutional authority structures, (2) participation interfaces, (3) communication and trust infrastructure, and (4) epistemic integration mechanisms. Together, these dimensions reveal how participation in the Dieng Plateau UNESCO Global Geopark operates as an institutional system shaped by centralized authority, persistent hazard exposure, and epistemic asymmetries. Rather than presenting participation as uniformly weak or strong, the findings demonstrate a pattern of partial, constrained, and uneven collaboration that has tangible implications for governance and risk management.

Institutional authority structures: Centralized governance and bounded participation

Across interviews and documentary evidence, governance authority in Dieng was consistently described as centralized, particularly in relation to geothermal development, hazard monitoring, and emergency decision-making. Strategic decisions concerning safety thresholds, land access, operational permits, and emergency protocols were primarily located within national and provincial institutions, reflecting regulatory accountability requirements and liability considerations typical of high-risk sectors (Newig & Koontz, 2014; Renn, 2017). Geopark management bodies and local government units occupied intermediary roles focused on coordination, facilitation, and implementation rather than on strategic decision-making (Zhuang et al., 2024). While these actors were visible and active in day-to-day geopark activities, their authority to influence decisions related to geothermal operations or hazard response was widely perceived as limited. This pattern aligns with governance research showing that participation often occurs within predefined institutional boundaries that restrict the redistribution of decision power (Emerson et al., 2012). Community participants frequently characterized participation as occurring downstream of decision formulation. Consultation processes were described as opportunities to receive information or express concerns, but not as mechanisms through which decisions could be meaningfully altered (Cumming et al., 2022). Importantly, centralized authority was not universally contested. Several institutional actors emphasized that hazard governance requires technical expertise, standardized procedures, and clear accountability chains, particularly in environments where errors may have fatal consequences (Basher, 2006). However, tensions arose when centralized control limited transparency or constrained deliberation over decisions with direct implications for community safety and livelihoods (Sambodo et al., 2021). These findings indicate that participation in Dieng operates within structural ceilings shaped by regulatory mandates rather than by deliberate exclusion. From a PGS perspective, authority structures condition the scope of participation interfaces and set the parameters within which collaboration can occur.

Participation interfaces: Procedural inclusion without decisional influence

Participation interfaces in Dieng included public consultations, community meetings, advisory forums, and project-related briefings. These mechanisms created multiple points of interaction between institutions and communities, consistent with UNESCO's emphasis on engagement and outreach (Bortolotto, 2024). However, their function was primarily informational and consultative rather than decisional. Community participants frequently described participation as episodic and reactive, often triggered by regulatory requirements or project milestones rather than embedded within continuous deliberative processes (Louis et al., 2025). While some acknowledged improvements in outreach and frequency of meetings over time, many expressed uncertainties about how their input influenced outcomes. Feedback loops, where institutions explain how community concerns were considered or why certain decisions were taken, were reported as inconsistent (Jackson et al., 2018). This configuration reflects what governance scholars describe as "procedural participation," where inclusion is achieved through formal processes but influence remains limited (Fung, 2015). In hazard-prone contexts, such arrangements can be particularly problematic because they may generate expectations of influence without providing mechanisms for accountability, thereby risking frustration and disengagement (Newig & Koontz, 2014). Institutional actors cited time constraints, regulatory timelines, and technical complexity as factors limiting deeper deliberation. While these constraints were presented as pragmatic, their cumulative effect was to position participation as an adjunct to decision-making rather than as an integral component of governance (Ansell & Gash, 2008). Within the PGS, participation interfaces thus functioned as transmission channels for information and concern, but not as sites of shared authority.

Communication and trust infrastructure: Risk, uncertainty, and credibility

Risk communication emerged as a central governance challenge in Dieng. Participants across all stakeholder groups emphasized the importance of timely, clear, and credible information regarding geothermal activity, gas emissions, and emergency preparedness. However, perceptions of communication effectiveness varied significantly. Institutional actors highlighted formal communication channels, including public announcements, signage, and coordination with local authorities (Tang et al., 2025). Community participants, by contrast, often described information flows as fragmented, particularly during periods of heightened uncertainty. Delays, technical language, and perceived inconsistencies between official statements and lived experience were cited as sources of confusion (Setyowati et al., 2024). Trust was closely linked to how institutions communicated uncertainty. Where uncertainty was acknowledged openly, and updates were provided, even when information was incomplete, participants reported higher confidence in institutional guidance (Santosa et al., 2021). Conversely, communication perceived as overly technical or dismissive of local observations undermined credibility. These findings are consistent with risk governance research showing that transparency and responsiveness are key determinants of trust under uncertainty (Hermans et al., 2022). Past experiences played a critical role in shaping trust. Communities

with direct or inherited memory of previous gas-related incidents reported heightened sensitivity to discrepancies between official narratives and environmental cues (Saptenno & Timisela, 2024). In such contexts, informal communication networks, such as community discussions and shared observations, became influential sources of risk interpretation. From a PGS perspective, communication infrastructure mediated how participation translated into trust or skepticism, reinforcing the systemic nature of governance dynamics.

Epistemic integration mechanisms: Recognition without decision relevance

Indigenous and local experiential knowledge was widely acknowledged by institutional actors as valuable for understanding environmental change and community concerns. Participants frequently referred to long-standing practices of observing changes in smell, vegetation, weather patterns, or animal behaviour as indicators of environmental instability. Despite this recognition, community participants consistently distinguished between acknowledgement and influence (Lansing et al., 2023). While local observations were sometimes invited during consultations, participants reported limited evidence that such knowledge shaped formal risk assessments, planning decisions, or emergency protocols (Jackson et al., 2018). This pattern mirrors findings from early warning systems research, where local knowledge is often referenced but rarely institutionalized within decision-making processes (Mercer et al., 2010; Vasileiou et al., 2022). Institutional actors cited challenges related to verification, standardization, and accountability. Experiential observations were described as difficult to integrate into formal systems governed by technical standards and auditable data requirements. These concerns reflect structural barriers identified in DRR scholarship, where epistemic hierarchies privilege scientific forms of evidence (Hermans et al., 2022). Notably, tensions were not framed as conflicts between “science” and “local knowledge.” Many participants emphasized the potential complementarity of knowledge systems, particularly for early detection and contextual interpretation. The absence of institutionalized translation mechanisms, rather than epistemological incompatibility, emerged as the primary barrier to epistemic integration.

Participation as a system: Interdependencies and governance consequences

Across all four components, the findings demonstrate that participation in Dieng operates as an interdependent institutional system rather than as isolated mechanisms. Constraints in one domain reverberated across others. Limited decision authority reduced incentives for sustained engagement; weak feedback loops undermined trust; and the absence of epistemic integration mechanisms diminished the perceived value of participation in risk-related discussions (Buckley et al., 2021). These interactions illustrate how participation deficits can become risk governance deficits. Procedural inclusion without decisional relevance generated ambiguity about responsibility and authority, particularly during periods of uncertainty. At the same time, the findings do not suggest complete governance failure. Incremental improvements in outreach and communication were evident, indicating partial and evolving collaboration rather than static tokenism. The PGS framework proved analytically useful in capturing this hybrid reality. It enabled examination of constrained yet meaningful forms of participation that operate within centralized authority structures, without assuming idealized collaboration or full power devolution. Overall, these findings demonstrate that participation in the Dieng Geopark cannot be understood by examining individual mechanisms in isolation. Authority structures delimit the scope of participation interfaces; participation interfaces condition the effectiveness of communication and trust-building; and communication practices shape whether local knowledge becomes epistemically influential or remains symbolic. These interdependencies reveal participation as a systemic governance condition rather than an additive set of engagement activities. The PGS framework captures how constraints in one domain reverberate across others, helping to explain why procedural inclusion may coexist with limited decisional influence and how such configurations shape risk governance outcomes under conditions of uncertainty.

DISCUSSION

This study set out to examine participation as an institutional system in a hazard-prone geopark context and to understand how participation design shapes governance, risk communication, and epistemic inclusion. By applying the Participatory Geopark System (PGS) to the Dieng Plateau UNESCO Global Geopark, the findings move beyond normative claims about participation to reveal the structural conditions under which participation becomes constrained, partial, or decision-relevant in practice. The discussion interprets these findings through the lenses of collaborative governance, risk governance, and epistemic justice, with particular attention to feasibility under centralized authority.

Reframing participation: From engagement activity to governance design

A central contribution of this study lies in reframing participation in geopark governance as an institutional design problem rather than as an engagement outcome. While UNESCO policy documents and much geopark scholarship emphasize participation as a defining principle of geopark identity (Simbaña-Tasiguano et al., 2025). The findings demonstrate that participation in Dieng is extensive in procedural terms but constrained in decisional terms. This pattern reflects what governance scholars describe as procedural inclusion without substantive power redistribution (Fung, 2015; Newig & Koontz, 2014). Collaborative governance theory cautions against equating participation with collaboration, emphasizing that collaboration requires institutionalized decision authority, accountability mechanisms, and sustained interaction (Ansell & Gash, 2008; Emerson et al., 2012). The Dieng case illustrates how participatory interfaces, such as consultations and advisory forums, can coexist with centralized authority structures that retain control over strategic decisions related to hazard management and geothermal development. Rather than interpreting this as a governance failure, the PGS enables a more precise diagnosis: participation operates within structural ceilings shaped by regulatory accountability, liability concerns, and sectoral mandates typical of high-risk governance domains (Renn, 2017). By shifting analytical attention from whether participation exists to how participation is configured institutionally, this study advances geopark governance research beyond legitimacy-focused narratives. It demonstrates that participation quality depends less on the number of engagement activities and more on how authority, communication, and epistemic inclusion are structured within governance systems (Fernández et al., 2024).

Participation design as a determinant of risk governance performance

A second major contribution concerns the relationship between participation design and risk governance outcomes. Although UNESCO positions geoparks as platforms for geohazard awareness and disaster risk reduction (Hutabarat, 2023), existing geopark research has rarely examined how participation structures influence risk communication credibility, trust, or preparedness. The findings from Dieng show that participation constraints are not merely symbolic; they have tangible implications for how risk information circulates and how institutional guidance is interpreted under uncertainty. Consistent with disaster risk governance scholarship, trust emerged as a relational and institutional outcome shaped by transparency, responsiveness, and acknowledgement of uncertainty (Hermans et al., 2022; Wojczewski et al., 2023). Where communication practices were perceived as one-directional or dismissive of local observations, trust weakened and communities relied more heavily on informal information networks. This supports arguments that risk is socially produced through governance arrangements rather than being managed solely through technical expertise (Maurischa et al., 2023). Importantly, the findings suggest that procedural participation without feedback loops can inadvertently undermine risk governance by generating expectations of influence that remain unmet. In hazard-prone contexts, such ambiguity may increase confusion during periods of uncertainty, weakening preparedness and response (Sumotarto et al., 2023). This insight extends geopark scholarship by demonstrating that participation design directly affects the functional performance of risk governance, not just perceptions of fairness or inclusion (Berglund & Pettersson, 2021; Halpern, Aydin & Halpern, 2025).

Epistemic justice as a governance mechanism, not a normative add-on

The study also contributes to debates on epistemic justice by demonstrating how epistemic inclusion is structured institutionally rather than achieved through recognition alone. In Dieng, Indigenous and local experiential knowledge was widely acknowledged by institutional actors, yet rarely translated into decision-relevant inputs (Urdapilleta-Carrasco et al., 2023). This pattern mirrors findings across early warning systems research, where local knowledge is often referenced but marginalized within formal decision processes governed by standardized evidence norms (Hermans et al., 2022; Vasileiou et al., 2022; Acar et al., 2025). Crucially, tensions were not framed by participants as conflicts between scientific and local knowledge systems. Instead, they were rooted in institutional practices that privilege auditable, standardized data due to accountability and liability pressures. This aligns with epistemic justice scholarship, which argues that epistemic injustice is produced through governance arrangements that define who is authorized to know and decide, rather than through overt exclusion (Fricker, 2007; Whyte, 2020). By treating epistemic integration as a core component of governance design, the PGS advances geopark research beyond cultural appreciation narratives. It shows that without institutionalized translation mechanisms, such as protocols for validating experiential observations or structured feedback loops, recognition risks remaining symbolic. In hazard-exposed geoparks, such symbolic inclusion may have material consequences if early signals or contextual interpretations are discounted during critical decision moments (Can & Soyulu, 2025).

Centralization, feasibility, and the limits of participatory reform

A recurring critique of participatory governance models concerns feasibility, particularly in contexts characterized by centralized authority and regulatory rigidity. The Dieng case confirms that full power devolution is unlikely in sectors such as geothermal risk governance, where safety standards, liability, and national policy priorities constrain decision-making autonomy (Newig & Koontz, 2014; Zhuzzhassarova et al., 2024; Weaver et al., 2024). Rather than viewing this constraint as a barrier to meaningful participation, the PGS conceptualizes participation as incremental, negotiated, and partial. Collaborative governance research emphasizes that collaboration often emerges through selective delegation, hybrid arrangements, and gradual trust-building rather than through wholesale institutional reform (Ansell et al., 2017). The findings support this view, suggesting that participation can become more decision-relevant through improvements in communication transparency, feedback mechanisms, and selective epistemic integration, even where authority remains centralized. This feasibility-aware approach responds directly to critiques that participatory governance frameworks risk idealism. By embedding institutional constraints into the analytical model, the PGS provides a realistic lens for identifying leverage points where participation can enhance governance performance without assuming unrealistic redistribution of power (Lukman & Hakim, 2024).

Theoretical implications

This study offers three key theoretical contributions. First, it advances geopark governance scholarship by conceptualizing participation as an institutional system rather than as an engagement outcome, addressing the participation, authority gap identified in recent literature. Second, it extends risk governance research by illustrating how participation design influences communication credibility, trust, and preparedness in hazard-prone heritage contexts. Third, it integrates epistemic justice into governance analysis as a practical mechanism shaped by institutional arrangements, rather than as a purely normative concern. The Participatory Geopark System functions as an analytical heuristic that captures how authority structures, participation interfaces, communication infrastructure, and epistemic integration mechanisms interact under constraint. Its value lies not in prescribing ideal governance models, but in enabling systematic assessment of participation quality and feasibility across geopark contexts characterized by uncertainty and centralized control.

Practical implications

From a practical perspective, the findings suggest that geopark managers and policymakers may benefit from focusing less on expanding the volume of participatory activities and more on strengthening institutional linkages between participation, communication, and decision processes. Enhancing transparency around decision rationales, formalizing feedback loops, and developing mechanisms for translating local experiential knowledge into decision-relevant formats may incrementally improve governance performance, even where authority structures remain centralized. These implications are intentionally framed as context-sensitive considerations rather than prescriptive solutions, recognizing the regulatory, political, and risk-related constraints inherent in geopark governance.

CONCLUSION

This study examined how participation operates in practice within a hazard-prone geopark context and how participation design shapes governance, risk communication, and epistemic inclusion. Drawing on an in-depth qualitative case study of the Dieng Plateau UNESCO Global Geopark, the paper demonstrated that participation in geopark governance is best understood not as an engagement activity or normative aspiration, but as an institutional system structured by authority relations, communication infrastructures, and knowledge hierarchies. By introducing the Participatory Geopark System (PGS), the study makes three primary contributions. First, it addresses a persistent gap in geopark scholarship by reframing participation as an issue of institutional design rather than visibility or involvement alone. The findings show that participation in Dieng is extensive in procedural terms but constrained in decisional terms, reflecting broader governance patterns in heritage and risk-regulated contexts where authority remains centralized. These reframing shifts analytical attention from whether participation exists to how decision rights, accountability, and influence are institutionally configured. Second, the study contributes to risk governance research by demonstrating that participation design has tangible implications for risk communication, trust, and preparedness in hazard-exposed landscapes. In Dieng, limitations in participation and feedback mechanisms shaped how risk information circulated and how institutional guidance was interpreted under uncertainty. These findings underscore that participation deficits are not merely symbolic concerns; they can translate into governance vulnerabilities in contexts where credibility and trust are central to effective risk management. Third, the study integrates epistemic justice into geopark governance analysis in a way that is

empirically grounded and feasibility-aware. While Indigenous and local knowledge were widely acknowledged, they were rarely rendered decision-relevant due to institutional norms that privileged standardized, expert-driven evidence. The PGS highlights epistemic integration as a governance mechanism shaped by authority structures and communication practices, rather than as a moral add-on or cultural gesture. Importantly, this study does not advocate idealized participatory reform or full power devolution. Instead, it explicitly recognizes the constraints imposed by centralized authority, regulatory accountability, and technical risk governance. The PGS is therefore offered as an analytical heuristic, not a prescriptive model, enabling systematic assessment of where participation is constrained, where incremental improvements are feasible, and where participatory claims may exceed institutional realities. Future research could compare PGS across geoparks, examine longitudinal changes in participation design, or integrate mixed methods approaches to explore relationships among participation, trust, and risk perception. Overall, the study positions geoparks as governance arenas where participation design matters not only for legitimacy, but for the quality and effectiveness of governance under environmental uncertainty.

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Ethical statement

This study was conducted in accordance with established ethical guidelines for social research involving human participants. Informed consent was obtained from all interview participants prior to data collection. Participants were informed about the purpose of the research, voluntary participation, confidentiality, and their right to withdraw at any time. Identifying information has been anonymized to protect participants' privacy. Ethical approval was obtained from the relevant institutional review body at Institut Pemerintahan Dalam Negeri.

Competing interests

The authors declare no competing interests.

Author contributions

All authors contributed equally to this study. They were jointly involved in conceptualization and research design, methodology development, data collection and analysis, literature review, theoretical framing, data interpretation, supervision, and the writing, review, and editing of the manuscript.

Data availability

The qualitative interview and observational data supporting the findings of this study are not publicly available due to ethical and confidentiality considerations. Anonymized excerpts and supporting materials may be made available from the corresponding author upon reasonable request.

AI disclosure

AI-assisted tools were used for language editing and clarity improvement during manuscript preparation. All substantive ideas, theoretical framing, analysis, and interpretations are the authors' own. The authors take full responsibility for the content of this article.

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