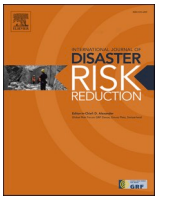
International Journal of Disaster Risk Reduction 142 (2026) 106245

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr



Reimagining disaster risk assessment: The role of information equity in vulnerable communities

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ARTICLE INFO

Keywords:
Informational equity
Risk communication
Media analysis
Vulnerability
Inclusive communication

ABSTRACT

Disaster risk assessment has traditionally focused on fatalities, economic losses, and physical damage, offering only a partial understanding of how risk is produced and experienced across social groups. This study advances an equity-centered approach by centering informational equity (the distribution of timely, comprehensible, and actionable information) as a critical yet under-examined dimension of disaster vulnerability. Through a multi-method case study of the 2023 Mortegliano hailstorm in Italy, we examined how information circulated across three interconnected communicative arenas: mainstream media, institutional actors, and vulnerable groups. Analysis of 121 media articles revealed that only 39% referenced vulnerable groups, predominantly framing vulnerability in economic terms, while rendering other dimensions invisible. Examination of 160 institutional social media posts showed that only 6.25% addressed vulnerable populations, and 20 interviews with institutional actors confirmed the use of standardized communication and revealed the *universal vulnerability paradox*. Interviews with 16 vulnerable individuals documented reliance on informal networks to compensate for institutional gaps, with socially isolated individuals experiencing acute informational exclusion.

These findings demonstrate that informational inequities emerge from systematic misalignments across the risk communication ecosystem, creating cumulative disadvantages for vulnerable populations. By reframing disaster risk assessment as a communicative process, this study contributes to reconceptualizing risk beyond traditional metrics, positioning information circulation as constitutive of vulnerability and resilience. Practical implications include integrating communicative metrics into emergency planning, institutionalizing accessibility audits, and embedding participatory co-design mechanisms within risk governance structures.

1. Introduction

During the past two decades, disaster risk scholarship has increasingly questioned the adequacy of assessment metrics centered solely on fatalities, economic losses, or physical damage [1,2]. While these indicators remain essential for quantifying the impacts of hazards, they offer only a partial understanding of how risk is produced, distributed, and experienced across different social groups. Emerging work in disaster studies, social vulnerability research, and risk communication demonstrates that knowledge, information

This article is part of a special issue entitled: Equity and Risk Assessment published in International Journal of Disaster Risk Reduction.

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https://doi.org/10.1016/j.ijdrr.2026.106245
Received 29 December 2025; Received in revised form 14 April 2026; Accepted 3 June 2026
Available online 4 June 2026

flows, and communication infrastructures play a decisive role in shaping exposure and adaptive capacity [3,4]. From this perspective, the circulation of information is not a technical add-on to emergency management but a socio-political process that influences who is able to prepare, respond, and recover, and who remains systematically disadvantaged. We advance informational equity as a framework that moves beyond documenting uneven information distribution (information asymmetry) to theorizing how the use of communication infrastructures actively produces differential vulnerability. Informational equity refers to the equitable distribution of timely, comprehensible, accessible, and actionable risk information across all population segments, regardless of barriers. Critically, this framework positions communication not as a neutral channel that reflects pre-existing inequalities but as a risk-generating process. When communication is designed for monolingual, digitally connected, institutionally trusting populations, it does not simply fail to reach others. It actively converts social differences into disaster vulnerability. These communicative exclusions precede and shape exposure, response capacity, and recovery trajectories, and thereby position information circulation as constitutive of risk itself [5–8]. This paper contributes to this shift from traditional impact-based metrics by advancing informational equity as a critical yet underexamined driver of disaster vulnerability. When individuals cannot access alerts, understand technical terminology, or trust institutional messengers, their capacity to take protective action diminishes. Such inequities are particularly consequential for populations already facing marginalization, including migrants, socially isolated individuals, people with disabilities, individuals with limited digital literacy, and those living in precarious socioeconomic conditions. Understanding how risk information circulates, and for whom, thus becomes central to any equity-oriented reconceptualization of disaster risk.

The disaster management cycle (spanning preparedness, response, recovery, and mitigation) provides a multiphase lens for examining informational equity. Although preparedness is often framed as a logistical or technocratic function focused on planning, training, and resource allocation [9], recent scholarship stresses that it is fundamentally social, requiring trust-building, empowerment, and meaningful engagement with communities [10]. Yet the equity challenges that emerge in preparedness do not dissolve as a disaster unfolds. Rather, informational inequities compound across phases: communities that cannot access pre-event risk education are equally disadvantaged in navigating response protocols, and those excluded from real-time emergency communication face heightened barriers to recovery procedures, from documenting damage to accessing compensation mechanisms. Preparedness strategies frequently adopt a "one-size-fits-all" logic that presumes a homogeneous, linguistically proficient, and digitally connected public [11]. This assumption disproportionately excludes some groups, who are also among those most exposed to the impacts of disasters, and its effects cascade from preparedness through response and into recovery, compromising both the fairness and the effectiveness of risk communication across the entire disaster lifecycle [12–14]. By situating informational equity within this full communicative arc, we highlight why communication cannot be treated as a neutral or auxiliary component of risk governance but must instead be understood as a core mechanism through which vulnerability is produced or mitigated at every stage.

To examine these dynamics empirically, the study focuses on an extreme weather event that affected Mortegliano, a village in the province of Udine (Italy), struck by an exceptionally severe hailstorm on 24 July 2023. The storm, which produced hailstones up to 19 cm in diameter, the largest ever recorded in Europe, caused extensive damage to buildings, vehicles, and agricultural land and formed part of a broader sequence of convective storms that struck northern Italy during the same period [15]. This event offers a strategically valuable context for investigating informational equity: the rapidity and unprecedented nature of the hazard created acute informational demands, while Mortegliano's heterogeneous population illuminates how communication barriers shape differential preparedness and response capacities. The event's scale and impact generated substantial institutional and media activity, providing rich material for analyzing how risk information circulated across multiple communicative arenas.

This paper examines informational equity through three interconnected communicative arenas: mainstream media, institutional actors, and vulnerable groups. Each arena provides a distinct vantage point for assessing how recognition, voice, and resource distribution (dimensions central to equity frameworks) shape the production, dissemination, and reception of risk and emergency information. The media analysis investigates whether and how vulnerable groups are made visible in public narratives, revealing whose experiences are deemed newsworthy and whose remain marginal. The institutional analysis examines public communication frameworks and emergency management practices, assessing whether official messaging accounts for heterogeneous audiences and differentiated needs. The community-level analysis captures lived experiences of navigating risk information, documenting the barriers that hinder access and the informal strategies people develop to compensate for institutional gaps.

By integrating these three perspectives, the study traces how informational inequities emerge not from isolated failures but from systematic misalignments across the risk communication ecosystem, which shape who can anticipate hazards, who can respond effectively, and who remains systematically disadvantaged. By reframing disaster risk assessment as a communicative process, this paper responds directly to calls for alternative approaches that move beyond traditional impact-based metrics. We argue that informational equity is fundamental not only for understanding how risk is unevenly produced but also for designing interventions capable of supporting more inclusive and resilient communities. When information fails to reach all segments of the population equitably, preparedness itself becomes stratified, and the protective function of communication [16] is unequally distributed. Positioning information circulation, its production, distribution, and accessibility, at the center of risk assessment enables a more complete understanding of vulnerability and opens pathways toward more equitable disaster risk reduction.

The remainder of the paper is structured as follows: Section 2 reviews relevant literature; Section 3 describes the data and methods; Section 4 presents findings from the media content analysis and interviews with institutional actors and vulnerable populations; and Section 5 discusses the implications of the study and offers concluding remarks.

2. Literature review

Over the last two decades, disaster studies have increasingly challenged technocratic and hazard-centered approaches to risk

assessment, emphasizing instead the social processes through which risk is constructed, communicated, and unevenly distributed. Within this broader shift, communication has emerged as a central analytical lens. Rather than functioning solely as a channel for disseminating expert knowledge, communication operates as a site where risk is interpreted, framed, and rendered actionable [17–19]. This reconceptualization critiques unidirectional models of emergency communication and highlights how information infrastructures shape differential capacities to anticipate, respond to, and recover from disasters. From this perspective, how information circulates across public arenas is not peripheral to risk assessment but constitutive of it. Preparedness has consequently been identified as a critical phase for understanding the communicative production of risk. While early emergency management literature largely framed preparedness as a logistical or procedural task focused on planning, coordination, and resource allocation [9], more recent work underscores its deeply social character. Staupe-Delgado and Kruke [20] further clarify that preparedness encompasses cognitive, behavioral, and social dimensions that extend well beyond logistical readiness. This reinforces the need to examine communicative capacity as a core component of preparedness planning. The effectiveness of preparedness depends not only on the availability of plans and warnings, but also on whether information is accessible, comprehensible, and trusted by different segments of the population. Communication failures at this stage can therefore translate directly into heightened exposure and constrained adaptive capacity, particularly for those already positioned at the margins of social and institutional systems. Scholars increasingly criticize static vulnerability indices and generalized assessment tools for their inability to capture how rapidly changing communicative conditions, such as the availability of information, the credibility of sources, or the accessibility of channels, shape people's capacity to act before and during an emergency [21].

The arenas in which risk communication unfolds play distinct roles in shaping how risk is represented, prioritized, and understood. Media coverage, for example, contributes powerfully to the public framing of disasters by selecting which impacts, actors, and experiences are made visible. Research on disaster reporting shows that while extreme events often receive extensive attention, media narratives tend to privilege generalized damage, dramatic imagery, and aggregate impacts over differentiated vulnerabilities [22,23]. The Social Amplification of Risk Framework [24] offers a complementary perspective, showing how media and social processes can both intensify and attenuate public perceptions of risk in ways that are systematically skewed toward visible, dramatic events and away from structural vulnerabilities. As a result, social inequalities in exposure, preparedness, and capacity to respond are frequently obscured, reinforcing a view of risk as uniform rather than stratified. This multi-arena structure resonates with Communication Infrastructure Theory (CIT) [25], which maps storytelling across micro-level actors (residents and community members) and meso-level actors (institutions and media organizations). CIT's concept of an integrated storytelling network, whereby micro and meso levels interact to co-produce shared narratives about community life and risk, offers a complementary lens for understanding why misalignments across communicative arenas produce compounding disadvantages for marginalized populations. Equally relevant is CIT's concept of the communication action context (CAC), which refers to the physical, technological, economic, and social conditions that either facilitate or constrain storytelling integration across ecological levels. Where these conditions are unevenly distributed, the CAC itself becomes a source of communicative exclusion, determining which actors can participate in shared risk narratives and which remain structurally outside them. Attending to the CAC alongside the storytelling network is therefore essential for understanding how informational inequities are not only relationally produced but also materially grounded. The present study draws on this multilevel logic to justify examining media, institutions, and vulnerable communities as interconnected rather than isolated sites of risk communication.

Public institutional communication occupies a similarly pivotal position in the preparedness phase. Risk communication by civil protection agencies and public authorities is typically guided by principles of technical accuracy, timeliness, and procedural clarity [26]. Although these principles are essential, a growing literature argues that they are insufficient if communication strategies implicitly assume a homogeneous, highly literate, and digitally connected public [12,13]. Standardized messages and channels may fail to reach or resonate with individuals facing linguistic barriers, limited digital access, cognitive impairments, or low levels of trust in institutions [27]. In such cases, preparedness planning risks reproducing existing inequalities by privileging those already equipped to access and interpret official information.

Central to understanding communicative dimensions of risks is the evolving concept of vulnerability. Disaster research has progressively moved away from viewing vulnerability as an inherent characteristic of individuals or groups toward understanding it as a relational and context-dependent condition [2,4,28]. Vulnerability arises from the interaction of social, economic, institutional, and environmental factors that shape people's ability to anticipate, cope with, and recover from hazards. This perspective emphasizes that risk is not solely a function of exposure to physical threats, but also of unequal access to resources, information, and protective capacities.

The multidimensional nature of vulnerability has been further articulated through distinctions among physical, social, economic, and environmental dimensions [29], as well as between contextual vulnerability, rooted in pre-existing conditions, and outcome vulnerability, which reflects the impacts of hazards after adaptive responses have been mobilized [30]. These distinctions underscore the temporal variability of vulnerability and challenge assessment models that rely on static or decontextualized indicators. Cutter's "vulnerability of place" framework reinforces this insight by highlighting how biophysical exposure and social response intersect within specific geographical and socio-economic settings, producing uneven risk landscapes [31,32].

Despite these conceptual advances, empirical research consistently shows that vulnerability assessments often struggle to capture the lived experiences of those most affected by disasters. Indicator-based approaches may identify "vulnerable groups" in abstract terms while failing to account for how vulnerability is produced and experienced through everyday interactions with institutions, media, and information systems [33]. This gap is particularly pronounced in relation to communication. Access to timely and comprehensible information, the ability to interpret warnings, and trust in institutional sources are rarely treated as core dimensions of vulnerability, even though they play a decisive role in shaping preparedness and response capacities. This communicative dimension of

vulnerability has been explicitly theorized by Hansson et al. [34], whose framework of communication-related vulnerability foregrounds the need for accessible, comprehensible, and actionable risk information as a prerequisite for protective action. This framework has been operationalized in disaster risk assessment and institutional preparedness contexts [35,36].

The relationship between vulnerability and disability illustrates these dynamics. Drawing on the social model of disability [37,38], disability is understood as the outcome of social and institutional barriers rather than individual impairment. This relational framing aligns closely with contemporary vulnerability theory and with intersectional approaches that examine how disability interacts with age, gender, and socio-economic status [39]. Importantly, disability and vulnerability are not synonymous. While disability can increase exposure to disaster risk due to structural and attitudinal barriers [40,41], it does not automatically imply vulnerability in all contexts. Research demonstrates that disabled people often exhibit remarkable resilience, supporting the need to focus on abilities alongside potential vulnerabilities [42]. These considerations are pivotal for preparedness and risk assessment, cautioning against homogenizing diverse experiences and capacities under a single category.

Revisiting vulnerability through a communicative lens reveals that exposure to hazard does not translate automatically into risk: individuals and groups may occupy similar physical spaces yet experience radically different levels of risk depending on whether risk information is timely, comprehensible, and actionable within their everyday contexts. From this perspective, vulnerability cannot be fully understood without considering the informational environments in which people are embedded. This insight is particularly salient in the preparedness phase, where risk is anticipated rather than endured. At this stage, vulnerability is closely linked to communicative conditions such as linguistic accessibility, digital connectivity, trust in institutions, familiarity with warning systems, and the availability of socially mediated sources of information. When these conditions are unevenly distributed, preparedness itself becomes stratified, reinforcing existing social inequalities and generating new forms of risk that are not captured by traditional assessment metrics.

Despite growing recognition of communication's importance in disaster management, systematic attention to informational equity as a core dimension of risk assessment remains limited. While scholars have examined communication failures in specific contexts and identified barriers faced by particular groups, few studies have explicitly theorized how unequal access to risk information operates as a structural driver of vulnerability across the disaster management cycle. This gap is consequential: if preparedness strategies do not account for the communicative conditions that enable or constrain protective action, they risk systematically disadvantaging those who most need support. Crucially, the need for equitable communication does not diminish as a disaster moves from preparedness into response and recovery. During the response phase, inequitable access to real-time warnings and evacuation guidance can determine survival; during recovery, the ability to access compensation mechanisms, navigate bureaucratic procedures, and document losses depends equally on inclusive communication design. Recognition of diverse needs, meaningful voice in communication decisions, and equitable distribution of informational resources (the three pillars of equity frameworks [cf. 5, 6]) remain analytically and practically central at every phase of the disaster management cycle. Conceptualizing informational equity as lifecycle-spanning is therefore essential for understanding how communicative exclusions accumulate, rather than simply occur at a single moment.

Building on these arguments, this study proposes communicative capacity as a critical dimension for rethinking disaster risk. Informational equity refers to the ability of institutions, emergency management agencies and media to produce inclusive and understandable communication that enables people in vulnerable situations to assess and use risk information in order to take protective measures. Unlike conventional indicators focused on losses or exposure, informational equity captures how risk is socially mediated and differentially experienced. By conceptualizing informational equity as a core dimension of emergency management, this study positions information circulation as a constitutive factor of disaster risk assessment and governance, aligning with equity-centered approaches that redefine risk beyond fatalities and losses.

3. Data and methods

To examine informational equity empirically, the study adopts a multi-method case study design [43,44] focused on the severe hailstorm that struck Mortegliano, a municipality in the province of Udine (Italy), on 24 July 2023. The event caused extensive damage to buildings, vehicles, and agricultural land, representing an extreme manifestation of climate-related risk in a small, socially heterogeneous community. Rather than treating the three communicative arenas as isolated domains, the study examines their interactions and misalignments, operationalizing informational equity as an emergent property of the entire communication ecosystem through methodological triangulation [45,46]. Mortegliano has approximately 2700 inhabitants and is located in a predominantly agricultural area of Friuli Venezia Giulia, a region with an above-average proportion of older residents. The storm's impact was devastating: damages to municipal heritage alone exceeded 15 million euros, and more than 95% of residential rooftops were destroyed, as were those of industrial and agricultural facilities [47]. Disaster risk management in Italy operates through a multi-level Civil Protection system: at the national level, the Department of Civil Protection coordinates strategy and resources; at the regional level, the Friuli Venezia Giulia Civil Protection directorate oversees planning and response; and at the municipal level, mayors hold legal responsibility for local emergency management, including issuing evacuation orders and activating local volunteer networks. Individual households are formally expected to maintain a degree of autonomous preparedness, including awareness of local alert systems and evacuation routes. In Mortegliano, direct interpersonal communication was central: the mayor maintained continuous physical presence among residents, while face-to-face exchanges and community WhatsApp groups served as the primary information infrastructure. Institutional social media, though less pervasive in this community, represent the most documentable and systematic expression of official communication choices and were therefore selected for analysis alongside the local print press.

Although data were collected in the immediate post-disaster period, this temporal positioning does not limit their relevance to preparedness and risk assessment. Drawing on Houston's [48] Disaster Communication Intervention Framework, post-event

communicative experiences are understood as generative inputs for future preparedness cycles: the barriers, informal strategies, and institutional gaps documented during recovery reveal the structural conditions that shaped, and will continue to shape, vulnerability before the next disaster. In this sense, recovery-phase data are not retrospective only; they are prospective, informing the design of more equitable preparedness communication.

3.1. Media analysis

The first empirical component consists of a qualitative content analysis [49,50] of local mainstream media coverage in the 30 days following the hailstorm (24 July–23 August 2023). Articles (N = 121) were retrieved from Messaggero Veneto, the most widely circulated daily newspaper in the Friuli Venezia Giulia region [51], using keywords related to location and event type ("Mortegliano," "alluvione (flood)," "maltempo (extreme weather)") through the Factiva database. Articles were screened for relevance to both the event and vulnerability. The screening adopted a bottom-up operationalization based on concrete references rather than predefined categories. From articles meeting both criteria, a sub-corpus of 30 articles was selected through systematic sampling of one article per day to ensure temporal representativeness and capture the evolution of media discourse throughout the post-event phase. This sampling strategy enabled in-depth qualitative analysis while avoiding bias toward particular moments of heightened media attention. Thematic coding focused on: (a) the journalistic style used; (b) presence of tailored information or guidance for specific groups; (c) type of vulnerability mentioned; (d) framing of risk; and (e) presence of specific actors (e.g., first responders, technical figures, NGOs). These items operationalize "inclusive" and "understandable" communication as empirically tractable constructs: items (b) and (c) assess recognition (whether diverse vulnerable groups are rendered visible and their differentiated needs acknowledged); item (e) assesses voice (whose perspectives and expertise are represented in public narratives); and item (b), read alongside item (d), assesses resource distribution (whether actionable information enabling protective action is made available to specific groups or remains addressed to an undifferentiated public).

This analytical strategy makes it possible to assess how vulnerability is rendered visible, acknowledged, or left implicit within mainstream journalistic narratives, providing a first communicative layer against which institutional practices and lived experiences can be comparatively examined.

3.2. Institutional communication analysis

The second component examines institutional practices combining digital content analysis and semi-structured interviews. We analyzed posts from the official Facebook pages of Regional Civil Protection (N = 109) and the Friuli Venezia Giulia regional authority (N = 51) during the month following the event. Facebook was selected due to its widespread use and centrality in institutional risk communication in Italy in 2023 [52]. Social media constitutes a privileged site for assessing informational equity in institutional communication for two reasons. First, it represents the channel through which institutions exercise direct, unmediated control over message design, format, and audience targeting, making it the most transparent indicator of whether equity considerations are intentionally embedded in official communication practice. Second, institutional social media output captures proactive, planned communication decisions rather than reactive or interpersonal exchanges, allowing assessment of the equity commitments built into preparedness and emergency communication before individual interactions occur. Posts referencing the disaster and containing elements of vulnerability were identified through manual screening and analyzed using the same thematic coding grid [50] applied to traditional media content, ensuring methodological consistency and enabling direct comparison. The analysis additionally assessed linguistic accessibility, specifically whether institutional posts were published exclusively in Italian or in multiple languages, as an indicator of whether communication was designed to reach non-native speaking residents. Applied to institutional posts, the same coding grid assessed inclusiveness by examining whether messages acknowledged differentiated needs (recognition), whether vulnerable groups were represented as active agents or merely passive recipients (voice), and whether actionable, accessible information was distributed across linguistic, digital, and sensory differences (resource distribution).

To complement the analysis of institutional practices, semi-structured interviews were conducted with institutional actors involved in emergency management (N = 20), including representatives from regional and municipal Civil Protection, local Fire Brigade and Red Cross units, and local administrators. Interviews lasted approximately 90 min on average and explored institutional perceptions of vulnerability, awareness of communicative barriers, and strategies employed to reach diverse audiences. Sample questions included: "How do you or your organization define vulnerability in disaster situations?"; "Are there groups you cannot reach?"; and "How do you conduct risk communication with people experiencing vulnerabilities?". This combined approach linked institutional intentions with actual communicative outputs, shedding light on the extent to which equity considerations translate into practice. Interview questions were structured around the same equity dimensions, examining institutional practices from the supply side: whether emergency managers acknowledged the differentiated needs of diverse populations (recognition), whether communication strategies incorporated input from or meaningful engagement with vulnerable groups (voice), and whether information was designed and distributed in ways that ensured practical access across linguistic, digital, and socioeconomic differences (resource distribution).

3.3. Interviews with vulnerable individuals

The third empirical component consists of 16 in-depth interviews with individuals experiencing vulnerability within the community of Mortegliano. Participants were recruited through a purposive sampling in collaboration with the municipality and the local Caritas branch, ensuring diversity in vulnerability profiles. The sample included older adult residents evacuated from damaged care

homes; Caritas beneficiaries experiencing intersectional vulnerabilities related to migration status, language barriers, and socioeconomic disadvantage, including family members with motor or intellectual disabilities; residents made economically and psychologically vulnerable by the emergency (e.g. small business owners, farmers); and care home and Caritas staff contributing insights as both citizens and caregivers. The diversity of the sample reflects an intersectional understanding encompassing socio-economic vulnerability, age-related fragility, and psychological vulnerability related to pre- and post-event trauma and anxiety.

Interviews lasted approximately 60 min on average and focused on information sources, tools used, and perceived communicative gaps. Sample questions included: "Before the crisis began, what kind of information did you receive or actively look for to prepare for the emergency?"; "Was the information easy to understand, timely, and relevant to your personal circumstances?"; and "What helped or hindered you in managing your situation during this time?". All interviews were audio-recorded with participant consent and transcribed verbatim. Analysis followed Grounded Theory [53], applying three coding stages (open, axial, and selective) to identify how participants navigate risk communication, rely on interpersonal networks, and interpret institutional messages within everyday constraints. This bottom-up approach illuminates how communicative environments shape differential capacities to respond to disaster risk.

4. Findings

This section examines how risk information circulated across three interconnected communicative arenas following the 2023 Mortegliano hailstorm: mainstream media, institutional actors, and vulnerable communities. Rather than treating these as isolated domains, our analysis reveals systematic misalignments that cumulatively disadvantage those already positioned at the margins. Media representations shape public recognition of vulnerability, institutional practices determine whose needs are operationalized in emergency planning, and community experiences reveal the consequences of these upstream failures. As illustrated in section 5.1, the three levels of analysis demonstrate that informational inequity is not an incidental communication failure but a structural feature of disaster risk production, one that operates through recursive loops in which failures at each level reinforce and amplify failures at the others.

4.1. Media representation of vulnerable groups and risk visibility

Despite extensive media coverage of the hailstorm (N = 121 articles over 30 days), only 39% (N = 47) referenced the specific needs and differentiated experiences of vulnerable people. Within our systematically sampled sub-corpus (N = 30), vulnerability was overwhelmingly framed through economic and material terms, rendering other dimensions largely invisible in public discourse. Farmers, livestock breeders, small business owners, shopkeepers, and families whose homes or livelihoods were severely damaged constituted the primary subjects of vulnerability narratives. These actors were consistently portrayed through metrics of economic loss, displacement, and limited access to resources for recovery, making socioeconomic vulnerability the most visible and recurrent category in media representations. The following headlines illustrate the dominant framing and the actors identified as the primary subjects of vulnerability:

> *"Devastated crops, destroyed greenhouses and warehouses: 7.5 million for agriculture"* (Messaggero Veneto, 26 July 2023)

> *"Mortegliano like a battlefield: 90% of house roofs destroyed"* (Messaggero Veneto, 29 July 2023).

Other forms of vulnerability received minimal attention. Older people, individuals with disabilities, and individuals with pre-existing health conditions were mentioned only sporadically, usually in connection with evacuations (for example, from care homes) or alongside age-related fragility. References to disability were limited (4 articles out of 30) and remained primarily descriptive without engaging with broader issues such as accessibility, autonomy, or differentiated exposure to risk. Families with young children appeared occasionally, mainly regarding housing damage or school disruptions. Overall, vulnerability was framed largely as material hardship, with limited recognition of its social, relational, or communicative dimensions. A further, less explicit form of vulnerability emerged in articles that documented civilians undertaking unsafe roof repairs, framing this as individual risk-taking rather than structural lack of support.

Actionable information and guidance appeared in only 13 of 30 articles, primarily addressing compensation procedures, safety warnings, and resource availability. A representative example is:

> *"Cars, homes, and businesses damaged by severe weather: here are the forms for obtaining reimbursements and how to apply"* (Messaggero Veneto, 5 August 2023).

These articles frequently included instructions on documenting damage, accessing compensation funds, and following Civil Protection guidelines, as well as warnings against unsafe repair practices. In addition, emergency response tools received more frequent mention (17 articles): temporary shelters, protective equipment, logistical support, dedicated telephone lines, and administrative assistance. However, this communication remained largely logistical rather than oriented towards social inclusion: messages were rarely tailored to specific vulnerable populations, and there was minimal engagement with community-based organizations, advocacy groups, or associations representing people in vulnerable conditions. No articles provided information in accessible formats, addressed linguistic barriers, or acknowledged differential capacity to navigate bureaucratic procedures.

The actors cited in the articles further reinforced this pattern. Governmental and administrative bodies, particularly local municipalities and regional authorities, dominated narratives, alongside emergency responders such as the Fire Brigade and Civil

Protection. Economic stakeholders were frequently mentioned in relation to damage assessment and losses. Expertise remained concentrated in emergency management and technical domains. Socio-humanistic, legal, or economic experts addressing social vulnerability, communication barriers, or long-term recovery inequalities were entirely absent.

The emotional-descriptive style dominated coverage (17 articles), relying on eyewitness accounts, vivid damage descriptions, and dramatic narratives of panic, and displacement. This approach foregrounded visible suffering, particularly among families and agricultural workers. Analytical framing (articles exploring the events, often drawing on detailed data and in-depth inquiries) appeared less frequently (6 articles), addressing institutional delays, emergency management challenges, and technical issues such as asbestos disposal or material shortages. Political framing (articles with political opinion and/or viewpoint regarding the event) was rare (3 articles), questioning institutional responsibility and resource allocation.

This media analysis reveals how vulnerability becomes selectively visible in public discourse. By prioritizing visible, material, and economically defined vulnerabilities, coverage obscured other forms, particularly those related to disability, age, and unequal access to information. This selective visibility shapes public understanding of who is affected by disasters and what constitutes adequate response, implicitly validating assessment frameworks centered on material damage while marginalizing communicative and accessibility dimensions.

4.2. Institutional communication and the framing of vulnerability

Analysis of institutional communication practices reveals a divergence: while emergency management actors declared awareness of differentiated social needs during interviews (N = 20), this recognition did not translate into communicative practice. Only 6.25% of official social media posts (10/160) were specifically tailored to the needs of vulnerable populations, with public messaging remaining standardized, monolingual, and oriented toward a presumed digitally literate, linguistically proficient audience.

Semi-structured interviews with representatives from the Regional and Municipal Civil Protection, Fire Brigade, Red Cross, and local administration confirmed that emergency managers possessed a shared, albeit often abstract, understanding that disaster impacts are socially mediated. Participants were able to identify specific groups prone to higher risk, consistently citing older adults, individuals with disabilities, non-Italian speakers, and economically precarious households. However, this recognition was frequently translated into an operational logic that prioritized standardization and efficiency. As one Civil Protection officer noted, the primary objective during an alert is *"to get the message out quickly and clearly to everyone."* This statement reflects a prevalent institutional worldview wherein efficiency is operationalized as the rapid dissemination of a standardized message, implicitly prioritizing speed over accessibility. Several interviewees employed what might be termed a "universal vulnerability" argument, the notion that in extreme events, "anyone may be vulnerable", partially to justify the absence of targeted strategies. This abstraction generates a paradoxical effect: while vulnerability is ostensibly prioritized in institutional rhetoric, its treatment as a broad, universal category dilutes specific accountability. By positing that vulnerability is everywhere, the system inadvertently fosters a diffusion of responsibility, where distinct obligations to dismantle linguistic, digital, or accessibility barriers are not assigned to concrete operational protocols. Consequently, this generalized acknowledgement results in practical inertia, leaving those with the greatest needs without targeted support. The limitations of this generalized approach became evident in frontline accounts. To illustrate this point, during the interview a member of the local Alpine Brigade described the management of a displacement camp. The presence of a Muslim population required different management strategies, since cultural needs, such as dietary restrictions and prayer schedules, together with linguistic barriers, generated a scenario that fell outside standard planning measures. As a result, responders were confronted with the need to devise new solutions in real time, highlighting how existing preparedness frameworks often fail to account for specific sociocultural contexts. As this Alpine Brigade member stated:

> "It happened to me to have 450 people in a reception camp, and 350, if not 380, were Muslim. So, we found ourselves facing a completely new situation … we discovered on site, figuring out what to do."

This reliance on improvisation rather than protocol illustrates how cultural and linguistic factors, when unaddressed in preparedness, emerge as acute management challenges during response.

The analysis of the 160 posts published on the official Facebook pages of the Regional Civil Protection (N = 109) and the Friuli Venezia Giulia regional authority (N = 51) during the month following the event reveals communication strategy predominantly oriented towards a standardized public, with minimal adaptation for specific social groups. The marginality of vulnerable populations within the official discourse is pronounced: as noted above, out of the total corpus, only 10 posts (6.25%) contained explicit references to specific vulnerable groups or their differentiated needs. On this sub-corpus, the thematic focus of the content emphasized administrative and technical dimensions: weather bulletins, damage quantification, procedural updates regarding compensation, and institutional announcements such as the declaration of the state of emergency. This distribution suggests that the primary function of the institutional channels was interpreted as the dissemination of logistical and bureaucratic information, rather than the promotion of inclusive preparedness or targeted risk education. In the limited instances where vulnerable groups appeared, they were consistently depicted as passive beneficiaries of institutional intervention (e.g., subjects to be evacuated or sheltered) rather than as active agents requiring specific, actionable information to enhance their own adaptive capacity.

Despite the demographic diversity of the affected area, all communication was monolingual (standard Italian), with complete absence of translated content for non-native speakers. No posts employed accessible formats, such as easy-to-read text or audio-visual aids essential for reaching individuals with sensory impairments or limited literacy. The only notable exception was a post promoting a "safety kit" for autistic individuals; however, this was a generic initiative entirely disconnected from the specific exigencies of the Mortegliano emergency. While this initiative demonstrates a potential for inclusive practice, it represents a specialized program rather

than systematic integration of inclusivity into standard risk communication protocol.

Interviews revealed no formal mechanisms for co-designing messages with vulnerable communities or pre-testing alerts comprehensibility with diverse audiences. Here, vulnerability was treated primarily as a logistical variable to be managed during the response, rather than a communicative dimension to be addressed during preparedness. A former deputy director of the Fire Corps highlighted the distinction:

> "In my opinion, from a physical standpoint, all people are reachable … What doesn't get through, however … is communication and information.".

This observation underscores that physical reachability alone is insufficient without corresponding informational access. Institutions may be capable of reaching anyone physically during evacuation, but if warnings, instructions, and preparedness information never reached them in comprehensible forms, the protective function of emergency management is fundamentally compromised.

The institutional analysis demonstrates how seemingly neutral communication practices produce systematic exclusion. By designing information infrastructures for a "standard citizen" - Italian-speaking, digitally literate, trusting of institutions, with stable connectivity-institutions convert social differences into informational inequity. Language barriers become communication barriers. Limited digital access becomes exclusion from compensation measures. Low institutional trust becomes failure to receive warnings. Standardization operates as a mechanism that actively distributes risk unequally: those who conform to the implicit "standard" receive protective information; those who deviate are systematically disadvantaged. The gap between institutional awareness and practice reveals that recognizing vulnerability is insufficient without operationalizing that recognition through concrete communicative design.

4.3. Experiences and communication practices of vulnerable people

Interviews with individuals in vulnerable situations (N = 16) reveal how individuals navigated risk information in practice, the barriers they encountered, and the informal strategies they developed to compensate for institutional gaps. A primary finding is that participants relied overwhelmingly on interpersonal networks and community-mediated channels to access and interpret information, with socially isolated individuals, particularly older adults, experiencing acute informational exclusion. For example, an interviewee whose father lives alone said:

> "*I was working at the restaurant when a colleague showed me a photo his uncle sent him. He said, 'Something is happening in Mortegliano. Look! Look! […].' Then my father called and said, 'Come pick me up!*".

Participants consistently described the event as unprecedented, with communication networks collapsing during the storm precisely when information was most needed.

Individuals in situations of vulnerability approached risk communication primarily through informal and relational channels. Few participants engaged with formal preparedness initiatives prior to the event. Public "safety evenings" organized by municipalities and Civil Protection and downloadable risk education content were perceived as reaching only a limited audience, mainly those already socially engaged or connected to volunteer networks. Several interviewees attributed low public engagement to lack of time, disinterest, or emotional resistance to contemplating distressing scenarios. This suggests that traditional preparedness communication, often framed as voluntary attendance at public meetings or proactive information-seeking, systematically excludes those with time constraints, caregiving responsibilities, or psychological barriers to engaging with risk. When the hailstorm occurred, official communication, especially through institutional social media channels, became an important reference point for those able to access it. However, this information was consistently supplemented, and in some cases replaced, by rapid informal circulation through personal contacts, neighborhood WhatsApp groups, and Facebook community pages.

Participants used information pragmatically for immediate decision-making and problem-solving. They relied on this information to understand the severity of the situation, locate assistance, secure temporary protection, and later navigate the bureaucratic procedures related to recovery and compensation. In several cases, interviewees reported learning about available aid or procedures only through word of mouth or messaging groups, rather than through direct institutional outreach. This reliance on informal channels was often described as necessary rather than preferred.

Participants identified multiple obstacles to accessing and using risk information during the event. Power outages, network congestion, and low battery levels disrupted digital communication precisely when it was most needed. Even when information was available online, several participants lacked the digital skills to navigate platforms, assess source credibility, or distinguish between official guidance and misinformation. Participants explicitly recognized the double-edged nature of digital platforms, which enabled rapid information sharing but also contributed to confusion during a highly stressful situation.

In the aftermath, navigating recovery procedures became a distinct informational challenge. Interviewees expressed a strong need for more structured, accessible, and inclusive communication systems. They emphasized the lack of clear, step-by-step guidance, particularly regarding recovery procedures, insurance claims, and interactions with contractors, and called for practical preparedness training embedded within the community. Italy's digital identity system (SPID), a requirement for accessing regional damage compensation, exemplifies how seemingly neutral administrative procedures create systematic exclusion. As an operator emphasized:

> "Some people had SPID but still could not apply on their own; others had no SPID at all because they did not even own a computer or smartphone".

This single procedural requirement effectively excluded households lacking digital infrastructure or literacy from compensation mechanisms, a form of structural vulnerability produced through communication design.

Importantly, participants stressed that effective risk communication should not depend solely on digital access or family support, but should include direct, in-person outreach and simplified formats tailored to diverse needs. Suggestions included transforming technical civil protection plans into user-friendly resources.

Overall, these experiences demonstrate that current risk communication systems systematically fail those already positioned at society's margins. While informal networks provided crucial compensatory infrastructure, they could not fully substitute for inclusive institutional design. The "protective function" of emergency communication was distributed unequally: those with robust social networks, digital access, linguistic proficiency, and institutional trust could navigate information; those without these resources could not.

Critically, this exclusion was not inevitable but produced through specific design choices: monolingual communication, digital-only channels, assumption of proactive information-seeking, and absence of direct outreach. By designing for a "standard" citizen, institutions converted pre-existing social inequalities into acute informational vulnerabilities during crisis. The reliance on informal networks also reveals a hidden equity issue: it transferred the burden of inclusive communication from institutions to already-marginalized communities. Volunteers, community organizations, and family members performed essential mediation labor without recognition or support. This arrangement may maintain a veneer of functional communication while obscuring systematic institutional failure to design equitable systems.

5. Discussion and conclusion

5.1. Cumulative disadvantage: How informational inequities compound

The three communicative arenas analyzed above do not operate in isolation but through mutually reinforcing dynamics that produce cumulative disadvantages for marginalized populations. Our analysis reveals three interconnected mechanisms through which informational inequity is systematically reproduced.

First, media invisibility reduces institutional accountability. When vulnerable populations are rendered invisible in public discourse, there is diminished public pressure on institutions to develop targeted communication strategies. The absence of media attention to linguistic barriers, digital exclusion, or accessibility needs signals to emergency management agencies that these issues are peripheral rather than central to disaster response. This media framing directly shapes what institutions perceive as their communicative responsibilities.

Second, institutional standardization amplifies pre-existing marginalization. The finding that only 6.25% of official posts addressed specific vulnerable groups reflects a broader institutional logic that treats communication as transmission rather than equity. By designing messages for a "standard citizen", emergency management converts social differences into informational barriers. Monolingual communication excludes non-native speakers. Digital-only channels exclude those without connectivity or devices. Bureaucratic procedures (like SPID requirements) exclude those without documentation or technical skills. Each seemingly neutral design choice functions as a sorting mechanism, determining who can access protective information and who cannot.

Third, communities lacking formal access become further isolated. Our interviews documented how vulnerable individuals relied overwhelmingly on informal networks (e.g. neighborhood WhatsApp groups, personal contacts, community organizations) to access and interpret risk information. While these networks provided crucial compensatory infrastructure, they could not substitute for systematic institutional inclusion. Critically, socially isolated individuals lacked access even to these informal channels. For these most marginalized populations, both formal and informal communication systems failed simultaneously, producing acute informational exclusion precisely when information was most critical.

These three mechanisms interact recursively: media invisibility legitimizes institutional inaction, which forces communities to rely on informal networks, which remain invisible to media and institutions, perpetuating the cycle (Fig. 1). The result is not merely informational asymmetry but the active, systematic production of vulnerability through communicative inequity. Those already

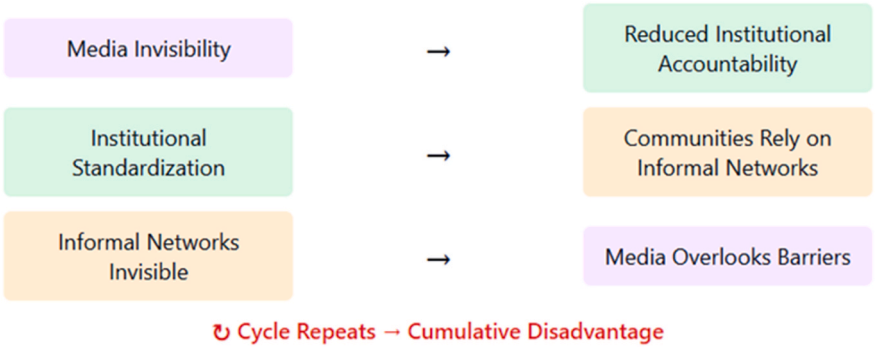

Fig. 1. Recursive loops of informational inequity.

positioned at society's margins experience compounding disadvantages at each level of the communication ecosystem.

This systemic analysis demonstrates that informational inequity is not an incidental communication failure but a structural feature of disaster risk production. Addressing it requires not fragmentary interventions at individual levels but coordinated transformation across the entire communication ecosystem.

5.2. Theoretical and practical contributions

Building on the patterns identified above, our findings advance disaster risk theory in three distinct ways. First, we introduce informational equity as a structural dimension of vulnerability that operates alongside, and interacts with, established dimensions such as economic, social, and physical vulnerability. While vulnerability frameworks recognize that exposure to hazards is mediated by social factors [2,4], communicative processes have remained largely peripheral to these conceptualizations. Our analysis highlights that informational equity is not merely a communication issue but a constitutive element of vulnerability itself: individuals may occupy identical physical spaces yet experience radically different risk levels depending on whether risk information reaches them in timely, comprehensible, and actionable forms. Importantly, this constitutive role is not confined to the preparedness phase: the communicative exclusions documented in our analysis, from the inability to receive pre-event warnings to the barriers encountered when navigating compensation procedures, span the full disaster management cycle. As the evidence from Section 4 demonstrates, informational equity must be understood as a lifecycle concern, one in which recognition, voice, and equitable resource distribution remain at stake from anticipation through recovery. This reframing positions communication not as auxiliary to risk assessment but as fundamental to understanding how risk is produced and distributed.

Second, we theorize what we term the "universal vulnerability paradox", an institutional logic whereby acknowledging that "anyone may be vulnerable" enables avoidance of operationalizing differentiated communication strategies. This finding contributes to critical disaster studies by revealing how progressive institutional discourse can mask structural inaction. When vulnerability is framed as universal and abstract, it paradoxically diffuses accountability for addressing concrete, differentiated needs. This rhetorical move allows institutions to appear equity-conscious while maintaining standardized practices that systematically exclude those facing linguistic, digital, cognitive, or socioeconomic barriers. The paradox operates as what we might call strategic abstraction: a discursive mechanism that reconciles equity values with efficiency-oriented operational logics. Understanding this mechanism is crucial for explaining the persistent gap between institutional awareness and practice documented across multiple disaster contexts.

Third, our three-arena analysis reveals that informational inequity emerges from ecosystem-level misalignments rather than isolated failures. Traditional communication assessments often focus on single actors (e.g., evaluating institutional messaging quality) or single moments (e.g., alert dissemination during response). By examining media, institutions, and communities simultaneously, we show how each arena's practices shape and constrain the others, creating emergent patterns of exclusion that no single actor intended but all collectively reproduce. This systems-level perspective has important implications: it suggests that interventions targeting only one arena (e.g., improving institutional messaging) will have limited effect if media continues to render vulnerability invisible and communities lack resources to access formal channels. Equity-centered risk assessment must therefore examine entire communication ecosystems rather than isolated components. This finding resonates with Communication Infrastructure Theory [25], which similarly argues that the integration, or fragmentation, of storytelling networks across micro and meso levels determines communities' collective capacity to act. The present study extends this logic in two directions. First, with respect to equity: fragmented communication ecosystems do not merely reduce collective action capacity, they distribute that reduction unequally, concentrating informational exclusion among those already at the margins. Second, with respect to the communication action context (CAC): the physical disruptions, technological inequalities, and socioeconomic barriers documented across all three arenas functioned as structural constraints on storytelling integration, demonstrating that communicative exclusion is not only relationally produced but also materially grounded in the conditions that constitute the CAC. Where CIT focuses on community agency and cohesion, the present study extends this logic to equity: fragmented communication ecosystems do not merely reduce collective action capacity, they distribute that reduction unequally, concentrating informational exclusion among those already at the margins. This finding also aligns with communication-related vulnerability research [34–36], which similarly demonstrates that informational exclusion is not attributable to single actors or moments but emerges from the interaction of institutional design, channel accessibility, and individual communicative capacity.

Translating these insights into practice requires three interrelated shifts in how disaster risk is assessed and managed. First, risk assessment frameworks must expand beyond standard technical indicators to include communicative metrics as operational variables, systematically documenting linguistic demographics, digital exclusion rates, literacy levels, and reliance on informal communication networks within at-risk communities. Municipal emergency plans, for example, could incorporate "communicative vulnerability indices" that identify populations facing systematic informational disadvantages, thereby guiding targeted outreach and resource allocation. Second, institutions should institutionalize systematic evaluation of communicative accessibility, moving beyond whether information is disseminated to whether it is practically useable by diverse audiences, conducting routine accessibility audits for preparedness and alert materials and ensuring multi-format and multi-channel strategy. From a risk assessment perspective, communication that is formally disseminated but practically unusable represents a latent risk factor undermining protective functions. Third, embedding participatory co-design mechanisms within risk governance structures requires establishing permanent working groups with representatives from vulnerable populations, such as disability advocacy organizations, migrant support networks, older adult associations, tasked with co-designing messages, pre-testing alerts, and evaluating dissemination channels. Participatory co-design serves both normative and instrumental functions: it addresses procedural justice while simultaneously improving technical quality and reach of risk and emergency communication. The inclusiveness of planning processes becomes an assessable dimension

that directly influences the distribution of protective capacity across populations.

By reframing disaster risk assessment as a communicative process, this study contributes to ongoing efforts to move beyond impact-based metrics toward more holistic, equity-centered approaches.

5.3. Limitations and future research

The single-case design, while providing rich contextual depth, focuses on a specific Italian municipality, and further comparative research across different geographical and cultural contexts would strengthen the generalizability of findings. The media analysis centered on the most widely circulated regional newspaper, which provided systematic coverage but could be complemented in future studies by examining digital-native outlets and national newspapers. The purposive sampling strategy for vulnerable populations, though ensuring diversity in vulnerability profiles, was facilitated through institutional contacts, and future research could explore additional pathways to reach individuals entirely disconnected from formal networks. The 30-day analytical window captured immediate post-event and early recovery dynamics but did not extend to longer-term recovery phases. Future research examining informational equity across the full disaster lifecycle, from preparedness through sustained recovery, would offer a more complete picture of how communicative exclusions accumulate and evolve over time; such studies could complement the present approach by examining pre-event communication across multiple channels, including radio, television, and printed materials, to capture how institutions attempt to reach diverse audiences before a disaster occurs and where informational inequities originate within the preparedness phase itself.

Despite these limitations, the multi-method approach and the integration of media, institutional, and community perspectives provide robust empirical grounding for conceptualizing informational equity as a critical dimension of disaster risk assessment.

Informational equity is not merely an ethical aspiration but a structural condition for resilience. Understanding how risk information circulates, to whom it is addressed, and under which conditions it becomes actionable emerges as central to equity-oriented disaster risk reconceptualization. The inclusivity of communication and equity of information access represent essential protection mechanisms, fundamental to building just and resilient communities.

Ultimately, achieving informational equity demands recognizing that disaster risk assessment encompasses not only measuring exposure to physical threats but understanding the socially embedded communicative processes through which risk is produced, distributed, and potentially mitigated. Only by positioning information circulation at the center of risk assessment can we open pathways toward truly equitable disaster risk reduction, where protection is understood not as a universal good but as a differentiated capacity requiring intentional, inclusive design. The alternative (i.e. maintaining communication systems designed for a fictional "standard citizen") is to accept that disasters will continue to disproportionately harm those already positioned at society's margins, reproducing and intensifying the very inequalities that equity-centered risk assessment seeks to address.

Ethical approval

All research activities adhered to ethical standards and were approved by the Institutional Review Board (IRB) of the Department of Mathematics, Computer Science and Physics, University of Udine. Participants provided informed consent, anonymity was ensured, and particular care was taken when engaging with potentially vulnerable individuals.

Funding sources

This work is part of the project SONAR-CITIES - Social Sciences Participatory Research-Action for Preparedness in Risk Management for Disasters and Health Emergencies in Europe's Cities. This project has received funding from the European Union's Horizon Europe Research and Innovation Programme (Call: HORIZON-CL3-2023-DRS-01 - Disaster-Resilient Society 2023), under grant agreement N° 101168315 - CUP G23C24001040006. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the REA. Neither the European Union nor the granting authority can be held responsible for them.

CRediT authorship contribution statement

Manuela Farinosi: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. **Chiara Piccolo:** Data curation, Formal analysis, Software, Writing – original draft, Writing – review & editing. **Alessandro Meneghini:** Data curation, Formal analysis, Software, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Manuela Farinosi reports financial support was provided by European Union. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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