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# A co-design approach for stakeholder engagement and knowledge integration in flood risk management in Vhembe district, South Africa

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**Introduction:** Participatory methods and collaboration among diverse knowledge holders are critical to soliciting multiple, and often competing, stakeholder perspectives and knowledge systems for enhancing flood management.

**Methods:** This study uses a participatory co-design workshop, post-workshop survey, and key informant interviews to establish the utility of co-design methods in engaging diverse stakeholders, including flood-prone communities, in flood management and/or adaptation in South Africa's Vhembe district. The co-design workshop brought together policymakers, practitioners, political actors, government agencies, local authorities, traditional leaders, and four flood-prone communities. It was conducted in the flood-prone region in the last quarter of 2023. At that time, discussions on mainstreaming climate change adaptation and disaster risk reduction in the development planning process were underway.

**Results:** The results show that the stakeholders were able to establish the key drivers of flood risk, challenges associated with flooding, current flood response measures, and barriers to effective flood response. However, an urgent need was for more effective flood response and an active role of flood-prone communities in the district. Stakeholders were able to use insights from the current dissemination of flood early warning systems and networks created during the workshop to call for action toward a community-based flood early warning system in the district. This call to action was premised on genuine collaboration between flood-prone communities and other key stakeholders rather than on any specific interventions. This was key to fostering more open discussions on enhancing the district's flood response and early warning systems.

**Conclusion:** The study concludes that the co-design approach with diverse knowledge holders is enriched by the local context and insights provided by the flood-prone communities (top-down collaborating with bottom-up) even beyond the workshop. This is useful for developing and implementing future community-based flood early warning systems.

## KEYWORDS

climate action, co-creation, flood risk, participatory disaster risk reduction, stakeholder engagement, transdisciplinarity, co-production

# 1 Introduction

Flood adaptation has become an increasingly urgent priority in the face of the escalating impacts of climate change, particularly in regions highly vulnerable to extreme weather events (Mirza, 2003). The complexity and multifaceted nature of flood risks, encompassing environmental, socio-economic, and governance factors, necessitates a more inclusive approach that integrates diverse perspectives and knowledge systems. In this context, the importance of local, site-specific knowledge of the local environment cannot be overstated, as it plays a crucial role in informing effective adaptation strategies to increasing flood risk (Grygoruk and Rannow, 2017; Kumari et al., 2024). While scientific and technical expertise, such as satellite imagery, field surveys, and advanced modeling remain essential, they must be complemented by the lived experiences and insights of the local communities who endure the direct consequences of flooding (Caretta et al., 2021). Though valuable, traditional flood management approaches in engineering and natural sciences often overlook the social dimensions of flood risk (Fuchs et al., 2017; Rittelmeyer, 2020). These methods primarily focus on data collection and technical solutions, often missing the diverse human experiences and needs essential for holistic flood adaptation. On the other hand, social sciences employ diverse methods to understand the social impacts of flood management. Nonetheless, they too, have struggled to fully integrate the variety of stakeholder perspectives into policy and practice (Bracken et al., 2015). This gap highlights the need for participatory approaches that actively involve local communities in co-creating adaptation solutions.

Since the early 2000s, there has been a significant increase in the recognition of the need for participatory disaster risk reduction initiatives, which advocate for the integration of local knowledge into development planning and policy processes (Vasileiou et al., 2022). Despite the widespread consensus on the value of public participation in disaster risk reduction, achieving effective and appropriate stakeholder engagement remains a persistent challenge (Dube and Munsaka, 2018; Andrew, 2018; Thapa and Pathranarakul, 2019; Imperiale and Vanclay, 2021). However, interdisciplinary and transdisciplinary methods that examine the stakeholder engagement process itself, rather than just the outcomes, offer promising avenues for deepening stakeholder engagement and ensuring that solutions are co-designed with, rather than for, local communities (McGlade et al., 2022; Slinger et al., 2023; Nguyen et al., 2024).

Co-production, co-creation, and co-design approaches have gained momentum in academia, particularly in the environmental and social science disciplines (Butterfield and Osono, 2020; Nguyen et al., 2024; Tarchiani and Bacci, 2024). They are increasingly considered effective in gathering, soliciting and integrating diverse stakeholder knowledge, expertise, insights, and perspectives. The co-design approach emphasizes stakeholder engagement in the design process to create solutions that align with their needs. We differentiate it from co-production, which involves shared knowledge generation and collective responsibility in delivering results, and co-creation, which is a broader term encompassing the entire collaborative process of a project, program or initiative (Nguyen et al., 2024). While seemingly different, these approaches form part of a continuum that challenges the boundaries between experts and non-experts, researchers/scientists and research participants, authorities and communities, etc. In addition to enhancing the effectiveness of flood

adaptation actions and responses, co-production, co-creation, and co-design often build capacities of stakeholders, particularly of those usually situated at the margins of decision-making (Nguyen et al., 2024). In this study, the co-design approach involved engaging individuals and organizations/institutions directly impacted by flood risk to contribute their diverse knowledge, expertise, insights, perspectives, and perspectives to improve the effectiveness of flood adaptation actions and responses in Vhembe district.

This study, therefore, explores and reflects upon the application of the transdisciplinary co-design methodology for flood adaptation, engaging a wide range of knowledge holders, including local communities, government agencies, academics, and non-governmental organizations. The aim is to address the limitations of current flood management policies and practices through effective and sustained collaboration among these stakeholders. Firstly, the methodological foundations of the co-design process are outlined, with a focus on its application in flood-prone communities within the Vhembe district of Limpopo Province, South Africa. The case study illustrates how collaborative efforts can be strengthened by actively and genuinely involving local communities in the design of flood adaptation strategies (Slinger et al., 2023). Through this study, we demonstrate that effective flood adaptation is achievable when diverse knowledge holders collaborate and actively engage in the process (O'Donnell et al., 2018; Pagano et al., 2019; Pasquier et al., 2020).

Vhembe district presents a unique case study for flood adaptation due to its socio-economic and ecological diversity, and the occurrence of high magnitude flood events (Munzhedzi et al., 2024). These flooding events pose significant threats to infrastructure, agriculture, biodiversity, and livelihoods. Traditional, top-down approaches to flood management have often failed to address the complex challenges in the district, underscoring the need for more participatory and inclusive approaches.

The paper is organized as follows: section 2 presents the theoretical foundations of the co-design process and key underpinnings. Section 3 describes the application of this method in the Vhembe district, providing an overview of local flood risks and the collaborative actions taken by stakeholders. Section 4 presents and discusses the key findings of the co-design workshop, including an evaluation of the method's effectiveness in promoting stakeholder engagement and commitment to action. Lastly, section 5 is the conclusion, which highlights the broader implications and applicability of the co-design methodology for flood management in the Vhembe district and beyond.

## 2 Theoretical foundations of co-design in flood adaptation

Co-design approaches emphasize collaboration and the active involvement of diverse stakeholders in the planning, decision-making, and implementation processes (Puech et al., 2021; Sánchez-García et al., 2022; Slinger and Kothuis, 2022). Theoretical foundations of the co-design method leverage key concepts such as participatory design, systems thinking, deliberative democracy, and transdisciplinarity to provide a comprehensive framework to address complex and dynamic challenges. This framework is uniquely suitable for engaging diverse knowledge holders in flood adaptation efforts.

The co-design approach is primarily rooted in participatory design, a methodology that emphasizes the active involvement of multiple stakeholders, including end-users, in the design process (Langley et al., 2018; Harrington et al., 2019). This ensures that the diverse needs, values, and knowledge of stakeholders are incorporated into the outcomes (Kusters et al., 2018). Within the context of flood adaptation, participatory design ensures the inclusion of diverse knowledge holders, ensuring that the perspectives of community members, scientists, policymakers, and others are considered in the co-production, co-creation and co-design of solutions (Tauzer et al., 2019; Minucci et al., 2020; Koutsovili et al., 2023). Complementing participatory design is the concept of social learning, which posits that learning occurs through interaction and collaboration among individuals (O'Donnell et al., 2018; Murti and Mathez-Stiefel, 2019; Ensor and de Bruin, 2022). Social learning involves exchanging and integrating diverse forms of knowledge, improving mutual understanding among stakeholders. Such collective learning processes are essential in developing robust and contextually relevant adaptation solutions (Murti and Mathez-Stiefel, 2019). Nonetheless, decision-making processes among multiple actors as they engage in discussions, potentially resolving complex issues together or addressing social dilemmas within their local contexts, have been limited in many regions (Jeffers, 2020). In this study, social learning emerges from interactions among diverse stakeholders constrained by sub-optimal adaptation options, often caused by a lack of information, communication, or collaboration. This results in stakeholders co-creating flood adaptation solutions that are both scientifically sound and locally relevant.

Co-design is also informed by systems thinking, which recognizes the interconnectedness and complexity of environmental, socio-economic, and cultural factors involved in flood management (Buchanan, 2019; Cabrera and Cabrera, 2023). Systems thinking provides a framework for understanding the multifaceted nature of flood risks and the interdependencies among various stakeholders, enabling a holistic approach to adaptation planning. Nonetheless, adaptation planning and response are often complex, often involving multiple stakeholders with differing goals and perspectives. Thus, applying complexity theory to co-design caters to the inherent uncertainties and dynamic changes in flood risk scenarios (Collopy, 2019; Buchanan, 2019). Therefore, integrating complexity theory into co-design makes the process more adaptable and flexible, ensuring iterative learning and continuous refinement of strategies in response to changing conditions.

In this study, the principles of deliberative democracy are also central to the co-design process with diverse stakeholders in flood adaptation. Deliberative democracy emphasizes the importance of inclusive, transparent, and reasoned debate among stakeholders (Willis et al., 2022). This ensures that all voices are heard and that decisions are made through collective deliberation, eventually resulting in more democratic and equitable outcomes. However, a closely aligned concept of “empowerment” promotes effective participation, particularly the active involvement of marginalized communities in decision-making (Shafique and Warren, 2018; Petriello et al., 2024). The theory of empowerment suggests that when stakeholders, especially those traditionally excluded from decision-making, are actively engaged in co-design, the resulting solutions are not only more equitable but also more effective. This is particularly relevant in flood adaptation, where the knowledge and experience of

local communities are critical to developing context-specific strategies (Pasquier et al., 2020).

Lastly, the co-design approach is inherently transdisciplinary, involving the integration of knowledge from multiple disciplines, sectors, and people. Transdisciplinary approaches are essential in addressing the complex challenges of flood adaptation as they encourage the co-production and co-creation of knowledge that spans scientific, local, and indigenous knowledge systems (Bracken et al., 2015). This study thus brings together diverse forms of expertise and knowledge through the collaborative and co-design processes to generate solutions to flood risks that are grounded in both empirical evidence and local realities. The integration of diverse knowledge systems was, therefore, a critical component of the co-design workshop. We considered that an effective co-design process creates space where expert and lay knowledge can be synthesized into practical and innovative solutions (Cash et al., 2003). In the context of this study, integrating knowledge and incorporating diverse perspectives are vital for developing flood adaptation strategies that are scientifically robust, contextually relevant, and sustainable.

## 3 Methods

### 3.1 Study area

This study focused on Vhembe district in Limpopo Province, South Africa, where four specific locations were deliberately chosen due to their frequent flood events and geographical context. These sites include Masisi, Madimbo, Tshenzhelani and Tshiungani in Musina local municipality (Figure 1). The Vhembe District covers a total area of 60,500 km<sup>2</sup>, characterized by hilly terrain with elevations ranging from 194 meters to 2,059 meters. The region experiences a semi-arid climate, with a rainy season extending from October to March. Average annual precipitation varies between 450 and 1,000 mm, mostly falling during December and January in the form of light rains or intense thunderstorms. The dry season spans from April to September, and summer temperatures typically range between 18°C and 38°C (Adeola et al., 2019). The natural environment is dominated by savannah ecosystems, featuring Mixed Lovelady Bushveld and Tzaneen Sour Bushveld vegetation types (Mucina and Rutherford, 2006). Key land use activities include residential areas, agriculture, game reserves, mining, forestry, and tourism (Ramaano, 2021). A small number of commercial farmers operate large-scale farms, focusing on activities such as tree plantations and fruit cultivation.

### 3.2 Data collection

This study employed a mixed methods approach to engage diverse knowledge holders in co-designing flood adaptation strategies in the Vhembe district in South Africa's Limpopo Province. The methodology consisted of three main components—a two-day participatory and collaborative co-design multi-stakeholder workshop, a post-workshop survey, and key informant interviews. These methods allowed for comprehensive stakeholder participation and feedback.

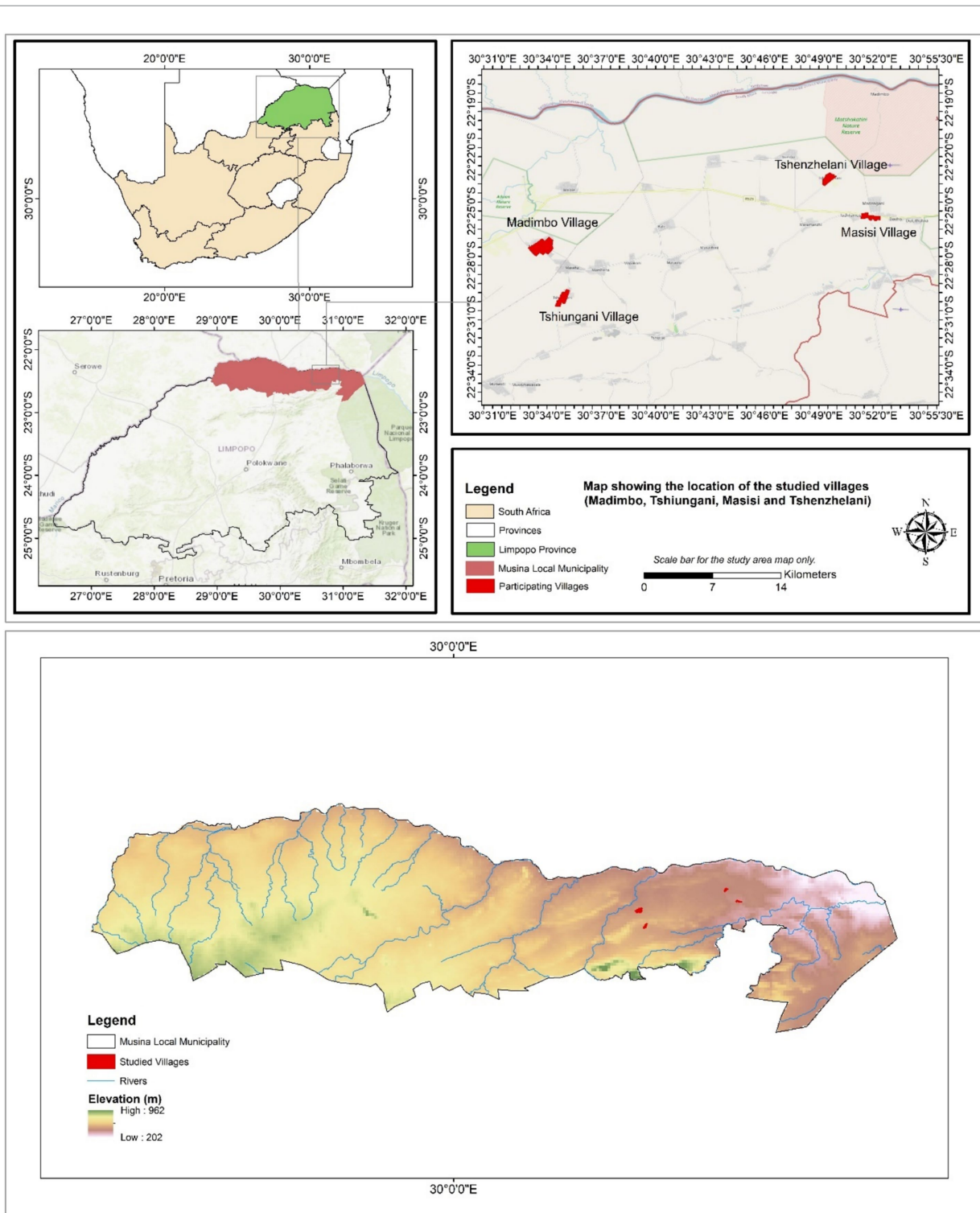


FIGURE 1 Location of flood-prone study villages (Madimbo, Masisi, Tshenzhelani, and Tshiungani) and elevation map of Musina local municipality in Vhembe district, Limpopo province, South Africa.

### 3.2.1 Multi-stakeholder co-design workshop

The core component of our methodology was a participatory and collaborative co-design workshop that brought together a diverse group of stakeholders, including members from four flood-prone communities (Madimbo, Masisi, Tshenzhelani and Tshiungani), traditional authorities, political actors, government officials,

scientists/researchers, and representatives from non-governmental organizations (Table 1). The workshop was co-organized by a research team from the University of Venda and the Vhembe District Disaster Management Centre. The research team was part of the academic stakeholders (scientists/researchers) whose role was not only to facilitate engagements and discussions but also to act as



TABLE 1 Co-design workshop stakeholders, stakeholder type, and role.

| Stakeholder   | Stakeholder type      | Role and/or contribution to co-design process  |
|---|-----------------------|--|
| Provincial Disaster Management Centre (PDMC)                  | Government            | <ul style="list-style-type: none"> <li>• Develop and approve legislation and policies.</li> <li>• Coordinate intersectoral collaborations.</li> <li>• Identify flood management priorities.</li> <li>• Publish and/or share national and regional climate data.</li> <li>• Responsible for providing weather and climate services.</li> <li>• Information on disaster management and responsible for coordinating intersectoral disaster management efforts.</li> <li>• Share information assistance and support to affected people and communities during and after flooding incidents.</li> </ul>  |
| District Disaster Management Centre (DDMC)                    | Government            |  |
| Limpopo Economic Development, Environment and Tourism (LEDET) | Government            |  |
| Department of Social Work (Social Development)                | Government            |  |
| Department of Health (Environmental Health)                   | Government            |  |
| Expanded Public Works Department (EPWP)                       | Government            |  |
| World Vision  | NGO                   | <ul style="list-style-type: none"> <li>• Share perspectives of NGOs on flood management and adaptation gaps.</li> <li>• Develop support policy and financial tools.</li> <li>• Provide funding for flood management (preparedness, mitigation, response, and recovery).</li> <li>• Support the development of innovations.</li> <li>• Implement flood management projects and/or support projects at the community level.</li> <li>• Develop and implement flood awareness campaigns.</li> <li>• Introduce and promote sound environmental practices.</li> <li>• Promote dialogue culture and networking.</li> <li>• Propose innovations in climate actions relevant to each community.</li> </ul> |
| Political actors (ward councilors)                            | Political actors      | <ul style="list-style-type: none"> <li>• Communicate community concerns and vulnerabilities to higher authorities.</li> <li>• Advocate for prioritization of flood management projects in local government budgets and planning.</li> <li>• Facilitate flood risk awareness and preparedness in communities.</li> <li>• Mobilizing resources and community volunteers during flood incidents.</li> <li>• Oversee proper implementation of projects and policies at the community level and hold local authorities accountable.</li> </ul>  |
| Community members/Ward committees (flood-prone communities)   | Local community       | <ul style="list-style-type: none"> <li>• Share lived experiences of flood-related impacts.</li> <li>• Share successes and failures of current flood response strategies.</li> <li>• Share critical knowledge and perspectives of local context.</li> <li>• Share current adaptation needs, aspirations, and opportunities in different livelihood activities.</li> </ul>   |
| Traditional leaders   | Traditional authority | <ul style="list-style-type: none"> <li>• Custodians of local culture and traditions.</li> <li>• Provide information on the local context.</li> <li>• Guiding first responders during flood risks.</li> <li>• Linking communities with local authorities and development planners.</li> <li>• Contribute community insights into the development planning process.</li> </ul>   |
| Musina Local Municipality                                     | Local authority       | <ul style="list-style-type: none"> <li>• Develop, maintain, and upgrade local infrastructure (e.g., drainage systems and roads).</li> <li>• Coordinate immediate emergency response activities.</li> <li>• Regulate land use to prevent construction in flood-prone areas and identify flood-risk areas in spatial plans.</li> <li>• Work with ward councilors to implement local-level flood education and preparedness programs.</li> <li>• Collaborate with district-level authorities to coordinate activities.</li> </ul>   |
| Vhembe District Municipality                                  | Local authority       | <ul style="list-style-type: none"> <li>• Develop regional flood management strategies, harmonizing efforts across different local municipalities.</li> <li>• Allocate resources to local municipalities to ensure effective flood management.</li> <li>• Facilitate collaboration between different sectors to ensure an integrated flood management approach.</li> <li>• Disseminate information to improve planning and early warning systems.</li> <li>• Support local municipalities during and post-flood events.</li> </ul>  |

(Continued)

TABLE 1 (Continued)

| Stakeholder                       | Stakeholder type | Role and/or contribution to co-design process  |
|-----------------------------------|------------------|--|
| Emergency Medical Services (EMS)  | Private sector   | <ul style="list-style-type: none"> <li>• Provide immediate medical assistance to injured or displaced individuals.</li> <li>• Assist in the safe evacuation of vulnerable populations.</li> <li>• Set up temporary medical stations or mobile clinics in affected areas to provide first aid and manage injuries.</li> <li>• Collaborate with other emergency services (fire, police, etc.) and authorities to ensure a coordinated response.</li> </ul>   |
| Vhembe North Agro-ecological Zone | Business         | <ul style="list-style-type: none"> <li>• Implement and promote sustainable farming techniques to reduce the vulnerability of agricultural production.</li> <li>• Invest in infrastructure to mitigate flood loss and damage.</li> <li>• Work with local authorities and government agencies to access weather forecasts and early warning systems.</li> <li>• Contribute to post-flood recovery by providing agricultural products to affected communities.</li> <li>• Support local disaster management efforts through food donations, tools, and manpower.</li> </ul> |
| Researchers                       | Academia         | <ul style="list-style-type: none"> <li>• Knowledge generation, brokering, co-creation, and transfer</li> <li>• Bridging the gap between scientific research and community-based knowledge.</li> <li>• Development of innovative flood management and climate actions.</li> <li>• Share emerging research findings and shaping future research.</li> <li>• Collaborate in knowledge dissemination, awareness raising, and capacity building.</li> </ul>   |

knowledge brokers and bridge the gap between scientific research and local knowledge. The diverse team of researchers and practitioners that organized the co-design workshop was purposefully constituted to facilitate considerations that span science, local knowledge, policy, practice, and local communities. The organizing team was mainly concerned with ensuring all key stakeholders relevant to flood management in Vhembe district were represented in the workshop. This is because ensuring diversity and equity in flood adaptation management discourse requires making radical changes that often deviate from usual practices. For instance, putting local communities at the forefront of such workshops is often overlooked or done to tick the boxes of “public participation” (Mugari and Nethengwe, 2022).

Participant selection was guided by the principles of participatory design and deliberative democracy to foster inclusiveness and reduce potential power imbalances (Hendriks, 2009). The research team began with a preliminary but comprehensive stakeholder mapping process. Thereafter, the research team deliberately engaged the District Disaster Management Centre in a pre-workshop planning meeting to identify additional stakeholders as well as potential workshop participants. Thereafter, the organizing team intentionally invited participants to ensure a broad representation of different stakeholders involved in flood management. These included flood-prone community members, traditional authorities, government departments, scientists, and practitioners. A gender lens was applied to ensure at least 50% representation of women from different age groups and socio-economic backgrounds. Women and previously marginalized stakeholders were specifically targeted through direct invitations and pre-workshop consultations to ensure their active and equal participation. Among the 38 participants, 17 represented the 12 expert stakeholders (authorities, practitioners and entrepreneurs) in Table 1 while seven were members of the research team. Fourteen non-expert participants were from the four flood-prone communities

and included community members, ward committee members, traditional leaders and ward councilors.

The facilitators of the co-design workshop were members of the research team who had prior research engagements and interactions with the stakeholders since 2022. Members of the research team were oriented on safeguarding against power dynamics inherent in rural, patriarchal communities. This orientation equipped them with strategies for managing hierarchies during the workshop (van Stokkom, 2005). Facilitators applied deliberative democracy principles during group sessions to ensure equal participation (Willis et al., 2022). Rotating speaking opportunities, gender-segregated focus groups, mixed-gender groups, and tools such as the wall of ideas, dotmocracy, paired talks, and anonymous contributions using written sticky notes ensured broader participation and silent voices. Facilitators also adopted non-hierarchical facilitation techniques, open-ended questions, and reflections to encourage participants to listen and learn from one another. Open dialogue during the workshop was informed by the principles of deliberative democracy, which allowed every participant an equal opportunity to contribute to the discussions. All these were aimed at encouraging constructive dialogue while mitigating any potential power dynamics that could stifle contributions from marginalized participants, especially women. In some sessions, traditional power holders were grouped separately from community members during certain activities to create a safe space for discussions, while in others, mixed-group sessions where traditional authorities, government officials, and community members (including women) worked together.

The 2-day co-design workshop was a culmination of several pre-workshop consultations, engagements, planning, bilateral meetings and research activities in the study are between 2021 and 2024 within the South Africa/Flanders Climate Adaptation Research and Training Partnerships (SAF-ADAPT) project. These pre-workshop engagements, including stakeholder mapping, targeted invitations, and an initial co-design consultative workshop in 2023 in Vhembe district familiarized

the participants with the co-design approach and workshop objectives. The workshop also incorporated elements of transdisciplinarity to co-produce knowledge that integrates scientific knowledge with local knowledge of flood-prone communities. Facilitators also took time to boost confidence and familiarity with the workshop before the different structured sessions to ensure active participation by all participants. In addition, facilitators infused systems thinking into the workshop by encouraging participants to explore flood management challenges as part of a complex, interconnected system (Buchanan, 2019). Other members of the research team played a key role of facilitating discussions and knowledge brokering during the discussions. For example, scientists and community members collaborated to identify flood-prone areas and solutions based on empirical data and lived experiences, while mixed group discussions allowed sharing of insights across sectors and disciplines. These collaborative design processes also allowed women to lead some activities on co-developing solutions which helped to break down gendered power imbalances. Facilitators encouraged participants to reflect upon the diverse perspectives shared throughout the sessions to promote social learning, mutual understanding, and collective knowledge building.

The workshop began with an introduction to the objectives, which were to:

- a) Co-establish the key challenges associated with flood risk in Vhembe district.
- b) Gather current perspectives on the drivers of flood risk, including barriers and enablers to effective flood management and/or adaptation or mitigation.
- c) Use insights to co-identify knowledge and capacity gaps that need to be addressed to ensure effective flood management and/or adaptation.
- d) Connect researchers, non-academic stakeholders, and vulnerable communities to enhance climate action.

This was followed by an overview of flood risks in Vhembe district by the local Disaster Management Centre. Participants were first divided into three groups to discuss and share their perspectives and experiences on flood risks and adaptation. These group discussions were guided by the first three objectives of the workshop. A facilitator for each group employed several participatory techniques (already described above) to foster active engagement and knowledge exchange among participants.

Summaries of discussions and co-design sessions were presented to the entire workshop for feedback after different sessions. Lastly, a co-design session allowed all the stakeholders to jointly identify the current knowledge and flood management gaps as well as capacity-building needs that would enhance flood management in the district.

### 3.2.2 Post-workshop survey

A post-workshop survey was administered to all participants to evaluate the effectiveness of the workshop and gather additional insights. The survey included both closed and open-ended questions to assess participants' perceptions of the workshop. The diversity of stakeholders, level of engagement and participation, relevance and usefulness of the workshop, and willingness to collaborate in future research initiatives were among the sought-out questions. Likert-scale questions were used to measure participants' agreement with these questions. Open-ended questions were used to solicit detailed

feedback on what participants found most valuable, knowledge and capacity gaps, and suggestions for action.

### 3.2.3 Key informant interviews

To gain deeper insights and validate the findings from the workshop and survey, key informant interviews were conducted with selected participants. These interviews provided an opportunity to explore specific issues in greater detail and gather expert opinions on flood adaptation strategies. Key informants were chosen based on their expertise, role in flood management, willingness to participate, and/or active participation in the workshop. A purposive sampling technique was used to ensure a diverse representation of perspectives. Semi-structured and open-ended questions were used, allowing for flexibility in exploring various topics while maintaining a consistent framework. Questions focused on participants' experiences with flood risks, their views on the workshop outcomes, and their recommendations for designing such workshops.

## 3.3 Data analysis

Thematic analysis was used to analyze qualitative data to identify common themes and insights from the qualitative survey data as well as the workshop and key informant interview transcripts. Post-workshop survey feedback was analyzed using descriptive statistics for quantitative questions. Findings from the key informant interviews were triangulated with workshop and survey data to ensure a comprehensive understanding of stakeholders' perspectives.

## 4 Results and discussion

Effective flood adaptation is a critical concern especially under a changing climate due to increased severity, duration, and frequency of extreme weather events. The multi-stakeholder co-design workshop addressed this concern by bringing together diverse stakeholders to discuss drivers of flood risk, management strategies, and collaboration among diverse stakeholders. The post-workshop evaluation and key informant interviews provided a comprehensive overview of participants' perceptions, highlighting both strengths and areas for improvement of not only the current management strategies but also the co-design methodology. The following results and discussion provide a synthesis of both the quantitative and qualitative data aimed at enhancing the effectiveness of flood management strategies in the Vhembe district and the co-design approach as applied in rural communities to guide ongoing and future efforts.

### 4.1 Stakeholder representation and diversity in the co-design process

There exists diverse knowledge and evidence on adaptation in Vhembe district, similar to many other rural settings (Pasquier et al., 2020; Vasileiou et al., 2022). However, this is often unfairly considered in flood management and development planning. A key objective of the workshop was to ensure diverse stakeholder representation. The multi-stakeholder co-design and consultative workshop brought together this diversity to inform and enhance more encompassing and

impactful flood adaptation research. The multi-stakeholder workshop attracted 38 participants representing 15 different stakeholder organizations. Participants included men, women, youth, and the elderly who were engaged in various livelihood activities from four flood-prone communities in the district. Despite a strong consensus that this objective was met, we had anticipated more than 25 different stakeholders based on the invitations sent. Nonetheless, those who attended represented diverse perspectives and interests in flood management in the district and beyond. While a broad range of stakeholder perspectives is essential for a holistic understanding of flood management (Tauzer et al., 2019; Fekete et al., 2021; Koutsovili et al., 2023), it is difficult, if not impossible, to bring all the desired stakeholders under one roof.

As local communities are critical to contributing their lived experiences and developing solutions, it was critical that they were represented hence the decision to have the workshop at a community hall central to the four flood-prone villages. This helped eliminate transport costs and reduce the distance to the workshops. Moreover, some participants, such as the elderly, were offered transport to and from the workshop venue. Despite the wide diversity of community members, some vulnerable groups, such as school-going children (6–18 years), were not represented. However, this group is vulnerable as they are not only affected by disruptions to their learning but in many rural areas, school children often cross rivers to attend classes. While future efforts must ensure the participation of school children, this must not interfere with their learning. Despite the absence of school children, their parents provided useful perspectives about their plight. Recent workshops are increasingly engaging diverse stakeholders, possibly due to the consensus that those vulnerable and at the forefront of climate change impacts must guide locally-led adaptation initiatives (Westoby et al., 2020; Rahman et al., 2023). Besides, vulnerable communities are entitled to define their socio-economic development trajectory and adaptation decisions that allow them to realize their desired futures.

Despite the absence of specific community groups, representatives from flood-prone communities play a critical role during co-design workshops (Meunier et al., 2022; Rahman et al., 2023; Teodoro et al., 2024). Community members in this study provided first-hand information on the impacts of flooding, drivers of flood risk, the current measures, the barriers to effective response, and challenges in accessing flood early warning information. Notwithstanding the several benefits, some studies have noted potential challenges, especially when not all stakeholders are represented. For instance, power dynamics and injustices often play out between local communities and institutions, resulting in tensions with other development priorities (Rahman et al., 2023).

Bringing previously sidelined or overlooked stakeholders to multi-stakeholder workshops (e.g., the flood-prone communities and groups in the community such as women and youth) is necessary but not sufficient in co-design processes (Neset et al., 2021; Slinger et al., 2023; McClure et al., 2024). There is a need to remove obstacles that may prevent them from participating fully and freely. Otherwise, their knowledge will remain with them (Slinger and Kothuis, 2022; Slinger et al., 2023). Our workshop used a variety of strategies to ensure broader participation. While grouping people with similar interests may encourage participation, this may limit the discussions. Similarly, while mixed groups enrich discussions, these may also scuttle discussions. For instance, participants were put in similar or mixed

groups as well as paired or allowed to decide individually just to encourage participation. In rural settings, traditional leaders can easily scuttle contributions from community members because of inherent power dynamics (van Stokkom, 2005; Hendriks, 2009). Trying to balance all this during the workshop is very challenging but necessary. Therefore, facilitators of such workshops must be able to adjust, adapt, and be flexible in order to respond to emerging needs. However, facilitators of such workshops must have a well-defined strategy and a toolbox to help them navigate the different dynamics that may emerge. In this study, facilitators were experts in community engagement, indigenous knowledge systems, and environmental science who constantly reviewed the proceedings and made necessary adjustments.

## 4.2 Drivers of flood risk and effectiveness of flood management in Vhembe district

The workshop's success in providing comprehensive insights into the drivers of flood risk, which included poor land-use planning, deforestation, poor agricultural practices, poor waste management, and blockage of drainage systems, is reflected by the 23 participants who strongly agreed or agreed that the perspectives discussed were insightful. Participants attributed several challenges, such as accelerated soil erosion, loss of agricultural land and crops, poor sanitation, waterborne diseases, damage to critical infrastructure and disruption of essential services, and loss of livelihoods to the increasing flood risk, particularly in the low-lying areas. This high level of agreement underscores the effectiveness of the workshop in raising participants' awareness of the multifaceted nature of flood risks beyond climatic factors, including geographic, governance, and socio-economic factors (Vojinovic et al., 2015; Sorg et al., 2018). Several studies elsewhere have highlighted how the non-climatic factors also identified in this study are increasing flood risk (Sorg et al., 2018; Dube et al., 2022).

While identifying the drivers and challenges of flood risk was the first key step, it was the depth of discussions on the non-climatic drivers of flood risk that proved crucial for developing effective adaptation strategies. For instance, understanding the root causes and contributing factors of flood risks allows stakeholders to design interventions that address these underlying issues rather than merely mitigating the symptoms. Besides, highlighting the impacts of flood risk, particularly on vulnerable populations, often drives home the urgency of adaptation measures (Okaka and Odhiambo, 2019; Mashi et al., 2020). Yet, future workshops should not only discuss in detail the localized drivers of flood risk and associated challenges but frame them within the context of broader social and economic impacts (Nhundu et al., 2021; Dube et al., 2022). This approach, including focusing on specific case studies in vulnerable communities, can foster a sense of shared responsibility and encourage collaborative efforts (Tauzer et al., 2019).

Among the current strategies and measures to curb flood-related loss and damage were improving waste management and clearing blocked drainage systems, constructing strong buildings, afforestation projects, banning unlicensed firewood trading, and improving agricultural practices. While the current study did not conduct comparative analyses of the different strategies, the co-design workshop was critical for initiating the process. Future co-design



workshops aim to enhance this aspect to highlight best practices (locally and globally) and provide valuable lessons that can be adapted to local contexts. However, the evaluation of the current flood management measures and strategies showed that they were generally ineffective, and this was mainly attributed to the interference from politicians, inadequate municipal budgets, and poor workmanship from service providers (e.g., construction of structures). With 23 participants strongly agreeing or agreeing with this observation, this suggests that the workshop provided clear and detailed information on current measures, their effectiveness and limitations, and the need for improvement. Several studies have highlighted key constraints in governance and management in many developing countries, with severe consequences on service delivery (Mashi et al., 2020; Chunga et al., 2023). For instance, political interference between opposing parties in local authorities and central government and the mismanagement of budgets have significantly limited service delivery in Zimbabwe's major cities (Makunde et al., 2018; Mudyamadzo and Nzwatu, 2018; Muchadenyika and Williams, 2018).

Furthermore, inadequate climate information services for flood risk response, inadequate flood early warning systems at the community level, lack of integration of local knowledge and modern/scientific early warning systems, inadequate flood response plans and/or awareness of impending flood risks, lack of knowledge and capacity among ward committees/volunteers and limited understanding of the drivers of flood risk at the community level were identified as key knowledge and capacity gaps that needed to be addressed. Understanding the gaps in the current flood management strategies is critical to identifying opportunities for innovation, as supported by certain studies (Tanwattana, 2018; Restrepo et al., 2020; Haque et al., 2024). Therefore, addressing knowledge gaps will empower stakeholders to implement effective flood adaptation measures.

### 4.3 Effectiveness of the co-design methodology

Many participants rated the co-design workshop highly and stated that their expectations were met. Such positive feedback reflects the co-design methodology's success in delivering valuable content and engaging participants. For a long time, adaptation research and flood management have often been uni-directional and top-down, with limited opportunities for interactive feedback (Kumari et al., 2024). For instance, researchers often conduct surveys and interviews with a set of questions that help solicit specific information, but anything outside that scope is usually not considered. However, such reliance on traditional methods of soliciting information is increasingly overwhelming vulnerable communities and usually results in research fatigue (Slinger et al., 2023). In this study, the diverse tools allowed visualizations of mind maps using flip charts, wall of ideas using sticky notes, dotmocracy using stickers, etc. This was aided by the availability of extensive floor and wall space to paste these visual aids. In addition, allowing participants to participate in diverse.

Similarly, flood management measures implemented by disaster managers are often imposed on the communities, yet local communities are the ones affected by the impacts of climate change (Rahman et al., 2023; Kumari et al., 2024). However, the co-design methodology employed in this study, together with the interactions among diverse stakeholders, proved valuable in soliciting diverse

forms of knowledge and evidence. In addition, ensuring that the aspirations of the vulnerable communities remained at the centre of the co-design process at least guaranteed that any solutions generated would address their challenges (Westoby et al., 2020). Therefore, to ensure this, future co-design workshops would incorporate the use of "serious games"—games played for purposes other than entertainment – to solicit knowledge that informs decisions, particularly for evaluating the effectiveness of co-created solutions (Khoury et al., 2018; Booth et al., 2020; Forrest et al., 2022).

Another key objective of the co-design methodology used in this study was to connect researchers, non-academic stakeholders, and vulnerable communities to enhance climate action. Although most participants (19) were positive that this was achieved, fewer (4) felt otherwise, indicating a need for improvement. For instance, some participants reported the absence of specific stakeholders at the co-design workshop as a missed opportunity. While connecting diverse stakeholders is never an event but a process that often takes time, the co-design workshop used in this study achieved far more in a short period. Effective stakeholder connection is vital for collaborative research and comprehensive flood management and adaptation strategies (Dube and Munsaka, 2018; Pagano et al., 2019). Employing various interactive and participatory methods to co-create adaptation research and solutions during the co-design workshops not only provides rich perspectives to address complex adaptation challenges but also increases participation and connection among diverse stakeholders. However, this does not mean foregoing traditional methods but integrating these into the co-design methodology, allowing diverse knowledge systems to inform solutions (Dube and Munsaka, 2018; Pasquier et al., 2020).

The workshop thus targeted all the relevant stakeholders in flood management in the district, with some even coming from the province. Moreover, to ensure that participants came prepared and to enhance their participation, stakeholders were given a comprehensive background and purpose of the workshop, including the opportunity to provide their input well before the workshop. The workshop venue was a community hall with a lot of floor and wall space and was equipped with necessary items, such as movable furniture, flip charts, markers, pens, sticky notes, blank cards, and projectors, which facilitated free movement, interaction, and engagement. All these were considered critical in connecting stakeholders during the workshop. However, there is a need to nurture these connections well beyond workshops or research studies, for instance, through follow-up meetings or leveraging digital platforms to facilitate ongoing communication and information sharing among stakeholders (Sánchez-García et al., 2022; Slinger et al., 2023). Although our co-design workshop did not have structured sessions for networking and collaboration, future workshops could have dedicated sessions for such.

### 4.4 Challenges and trade-offs of the co-design method

Notwithstanding its relevance in addressing complex challenges, the co-design methodology of engaging diverse stakeholders, including vulnerable and marginalized communities, in enhancing flood management and/or adaptation solutions in the Vhembe district presented significant challenges and trade-offs. For instance, despite

efforts to ensure equitable participation, a balanced representation of all stakeholders, especially those from marginalized communities, was not achieved entirely. In addition, similar to many other co-design initiatives, dominant voices from more resourced and influential stakeholders tended to overshadow those from vulnerable areas, leading to an imbalance in the contributions and perspectives considered. Besides, creating space for marginalized voices or previously underrepresented stakeholders requires that others yield space, resulting in winners and losers within the co-design process (Pohl and Hadorn, 2008; Rahman et al., 2023). For instance, prioritizing the inclusion of vulnerable communities may necessitate reducing the influence of more established stakeholders, such as political actors and government agencies, which can lead to tensions. Some stakeholders may feel sidelined or believe their input is undervalued, particularly if their traditional methods or perspectives are not prioritized in favor of more inclusive or innovative approaches (Begg, 2018; Suhari et al., 2022). This tension can manifest in formal complaints or dissatisfaction among participants who perceive the process as flawed or biased.

Moreover, these equity-seeking efforts come with significant costs. For example, allocating resources to ensure the participation of marginalized communities—such as providing transport or translation services—requires financial resources. Therefore, limited budgets mean trade-offs must be made between various priorities, such as funding for broader geographic representation versus deep engagement with specific communities (Cooper, 2023). Although we tried to minimize costs associated with participation by hosting the co-design workshop locally (i.e., in the flood-prone communities), other key stakeholders from elsewhere did not attend. Even when the co-design workshop was held locally, certain community groups of interest (e.g., farmers, women's groups, etc) were not represented. The decision to include influential stakeholders such as political actors and traditional authorities may also scuttle the participation of vulnerable communities. All these decisions can strain the co-design process and lead to further disparities in whose voices are ultimately heard and valued. Ultimately, the trade-offs inherent in the co-design approach are necessary to address the inequalities that exist in stakeholder engagement (Ezzatian and AminZade, 2024). While these trade-offs can be challenging and may result in some stakeholders feeling excluded or undervalued, they are essential steps toward creating more inclusive and effective flood management and/or adaptation solutions that genuinely reflect the needs and knowledge of flood-prone communities.

## 4.5 Future of co-design methodology in flood management and/or adaptation

Advancing co-design methods in flood adaptation hinges on creating more inclusive and collaborative environments. The overwhelming willingness of the workshop participants to participate in future co-design processes and research suggests a strong foundation for ongoing collaboration. The goal of these inclusive spaces is to enhance our collective ability to envision and implement innovative and feasible solutions for flood resilience. At the core of this effort is the need to foster collaborations that bring together diverse perspectives and expertise. The enthusiasm shown by the participants can be harnessed to build a robust network of stakeholders committed

to advancing the effectiveness of flood management and/or adaptation solutions. Some participants of the co-design workshop expressed a desire to forge new partnerships focused on areas such as community-driven adaptation strategies, the integration of local knowledge in decision-making processes, and the co-production, co-creation and co-design of flood risk management solutions. These examples underscore the importance of expanding the co-design framework to include a broader range of voices and approaches.

In addition to fostering innovation, inclusive spaces in co-design are essential for promoting justice and equity (Begg, 2018; Rahman et al., 2023; Bharwani et al., 2024). Historically, local and indigenous communities, which are often the most affected by floods, have been marginalized in the development of adaptation strategies (Dube and Munsaka, 2018; Hao and Lun, 2024). The ongoing efforts to address this imbalance represent a critical step forward, but much more needs to be done. Ensuring that underrepresented groups have greater access to decision-making processes, funding, and opportunities to contribute to flood management and/or adaptation strategies is a long-term commitment that all stakeholders must embrace. This includes not only those directly involved in flood management but also academia, media, funding agencies, practitioners, traditional leaders, NGOs, and intergovernmental organizations. To facilitate this, future workshops could include sessions focused on outlining potential collaborative research projects and identifying interested participants. Furthermore, establishing clear channels for communication and collaboration, such as working groups or research consortia, can help maintain engagement and drive collective action.

The co-design methodology for engaging diverse stakeholders in flood management and/or adaptation in this study reveals several inherent trade-offs in striving for equity and inclusion. Expanding the diversity of voices and expertise within co-design processes inevitably requires some groups to make room for others (Slinger et al., 2023; Cooper, 2023). However, these trade-offs are valuable, as they open new possibilities for collaboration and innovation that can significantly advance flood management and/or adaptation efforts. We see these trade-offs as worthwhile and look forward to the continued expansion and enrichment of the flood management and/or adaptation community through more inclusive co-design methods.

## 5 Conclusion

This study demonstrates that a co-design approach is an effective mechanism for engaging diverse stakeholders in flood risk management, particularly in flood-prone communities similar to the studied communities in the Vhembe district in South Africa. Through leveraging and integrating participatory design, social learning, systems thinking, deliberative democracy, and transdisciplinary collaboration, the study successfully facilitated the examination of flood risk drivers and the co-design of locally relevant adaptation strategies with diverse stakeholders. The findings highlight the importance of inclusive stakeholder engagement in disaster risk reduction and meaningful participation in enhancing community ownership, including the sustainability of flood management initiatives. The study underscores that while co-design enriches collaboration among diverse stakeholders, it is not without challenges. Certain challenges encountered in this study reflect some broader and systemic issues within co-design processes, where balancing the

inclusion of diverse perspectives with practical limitations remains an ongoing struggle. Going forward, critical considerations for co-design processes should border around navigating the inherent power imbalances between different stakeholder groups, logistical constraints, and the need for continuous engagement beyond workshops. Addressing these barriers requires long-term commitment, iterative engagement processes, and mechanisms to sustain stakeholder collaborations beyond initial interventions.

The research team acknowledges the limited generalizability of the findings of this study beyond the study area due to the limited focus on a few local communities in the Vhembe district of South Africa. However, the co-design framework applied in this study is broadly applicable. It can be extended to other regions with similar environmental challenges, particularly those contexts with comparable socio-economic, climate-related and agroecological vulnerabilities. While the methodology provides valuable insights applicable to similar settings, aligning local adaptations with specific socio-cultural and governance contexts remains critical. Future research should explore the long-term impacts of co-design interventions and assess how community-led approaches evolve over time. Expanding the scope to include diverse socio-economic and socio-cultural groups, more marginalized communities, and other geographic locations, would further enrich co-design outcomes. This study, therefore, contributes to the growing body of knowledge on participatory disaster risk reduction by demonstrating the practical application of co-design in flood adaptation. The study's emphasis on stakeholder inclusivity, local knowledge integration, and collaborative learning provides a replicable framework for enhancing flood resilience in vulnerable communities. Future efforts should continue refining co-design methodologies to maximize their effectiveness and long-term impact on climate adaptation and disaster risk reduction strategies.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Author contributions

EM: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Validation,

Visualization, Writing – original draft, Writing – review & editing. NN: Conceptualization, Formal analysis, Funding acquisition, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing. AG: Conceptualization, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Generative AI statement

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