DISSERTATION

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Exploring capacity gaps for improved disaster risk reduction within UNESCO-designated heritage sites in Africa

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Dedication

To Chinazaekpere, Akachukwudiya and Ihechukwumere – for all you endured throughout this work. To Ma Celestina Eze and Late Pa Gilbert Duhu Eze – for your numerous sacrifices and prayers for me.

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With utmost appreciation,
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29.07.2024

Abstract

The increasing occurrence of hazardous events like floods and droughts, intersecting with socio-environmental exposure and vulnerability, has escalated disasters, particularly impacting vulnerable regions in Africa. Natural and cultural heritage sites in Africa are vital for sustainability, linking past, present, and future generations while offering significant socioeconomic tourism-related benefits. Threats to these sites in Africa numbering 268 can alter host communities' identities and deprive future generations of their benefits. However, disaster exposure, vulnerability, and threat levels at these sites remain understudied. Also, the capacity levels and gaps of key actors are largely unknown. Addressing these gaps is crucial for sustainable protection against disasters and mitigating significant threats posed by natural and human-induced hazards.

The dissertation presented here uses exploratory cross-sectional mixed methods and comprehensively assesses disaster risks and capacities in Africa, aligning with the United Nations' Sendai Framework for Disaster Risk Reduction. It aims to answer two overarching research questions: (i) What is the level of exposure of heritage sites to disaster hotspots in Africa? And (ii) What is the capacity level of African UNESCO site actors for disaster risk management? These two broad questions are further split into seven sub-questions. The research utilized both primary data from surveys and interviews with UNESCO actors, and secondary data from relevant policy documents and the Index for Risk Management data. Analytical techniques, including descriptive statistics, mean difference tests, discrepancy analyses and machine learning, were employed to address the research questions.

The assessment reveals that 41 % of UNESCO-designated heritage sites in Africa are located in disaster hotspots. The nature of disasters in Africa is found to be predominantly social, and the vulnerability of these sites to increasing disaster risks is primarily driven by factors such as violent conflicts, population displacement, and poverty. Furthermore, the results indicate that while UNESCO actors in Africa possess strong competencies in disaster risk management, there is a noticeable gap in adopting innovative strategies and technologies for risk reduction. Additionally, hazard exposure, risk perception, and resource availability significantly influence disaster preparedness at these sites.

In conclusion, this thesis emphasizes the urgent need for extensive policy changes to address interconnected social disaster risk drivers in Africa and the imminent threats posed to the numerous heritage sites within hotspots. It also highlights capacity deficiencies among UNESCO actors demonstrating the importance of tailored professional development programs to enhance disaster risk management effectiveness. Bridging these gaps is essential for reducing disaster risk exposure to Africa's collective heritage, advancing resilience and sustainable futures.

Zusammenfassung

In Afrika haben sich Naturkatastrophen wie Trockenheit und Hochwassserereignisse in den letzten Jahrzehnten zunehmend verschärft. Hierfür ist zum einen die Zunahme von Gefährdungsereignissen verantwortlich, vor allem aber auch eine verstärkte sozio-ökologische Exposition und Verwundbarkeit der Gesellschaft. Bei der nachhaltigen Entwicklung Afrikas spielen Natur- und Kulturerbestätten eine große Rolle, da sie Vergangenheit, Gegenwart und Zukunft miteinander verbinden und erhebliche sozioökonomische Potenziale im Tourismus besitzen. Eine Gefährdung dieser 268 Stätten kann sich negativ auf die lokalen Gemeinschaften auswirken, indem diese in ihrer Identität beeinflusst und künftige Generationen möglicher Potenziale beraubt werden können. Die Gefährungsexposition, die Verwundbarkeit und die Intensität der Bedrohung an diesen Stätten sind jedoch kaum untersucht. Weitgehend unbekannt ist außerdem, wie gut die Hauptakteurinnen und –akteure dieser Welterbestätten auf mögliche Risiken vorbereitet sind und wo Wissenslücken herrschen. Ein nachhaltiger Schutz der Stätten vor Katastrophen und die Abmilderung möglicher Folgen bedarf daher einer umfassenden Untersuchung der möglichen Gefahren und der Resilienz der Akteure an Welterbestätten.

Diese Dissertation nutzt einen Mixed-Methods Ansatz in einer explorativen Querschnittsstudie um im Einklang mit dem Sendai Framework for Disaster Risk Reduction der Vereinten Nationen das Katastrophenrisiko und die Kapazitäten der Welterbestätten auf Katastrophen zu untersuchen. Die Studie beantwortet zwei übergeordnete Forschungsfragen: (i) Wie viele der Welterbestätten in Afrika liegen in Katastrophen-Hotspots (Risikobewertung)? Und (ii) Wie groß sind die Kapazitäten der Akteurinnen und Akteure in afrikanischen UNESCO-Stätten um angemessen auf das Katastrophenrisiko zu reagieren (Kapazitätsbewertung)? Diese beiden Hauptfragen werden in sieben Unterfragen aufgeteilt. Diese Studie nutzt sowohl Primärdaten aus Umfragen und Interviews mit UNESCO-Akteurinnen- und Akteuren als auch Sekundärdaten aus relevanten offiziellen Dokumenten und den INFORM-Risikodaten. Verschiedene Analysetechniken, darunter deskriptive Statistik, Mittelwert-Differenztests, Diskrepanzanalysen und maschinelles Lernen, wurden eingesetzt, um die Forschungsfragen zu beantworten.

Die Risikobewertung zeigt, dass 41 % der von der UNESCO ausgewiesenen Welterbestätten in Afrika innnerhalb von Katastrophen-Hotspots liegen. Bei den für die Welterbestätten relevanten Katastrophen handelt es sich überwiegend um gesellschaftliche Ereignisse. Die Verwundbarkeit der Stätten gegenüber zunehmenden Katastrophenrisiken wird hauptsächlich durch Faktoren wie gewaltsame Konflikte, Völkerwanderungen und Armut angetrieben. Darüber hinaus zeigen die Ergebnisse, dass die UNESCO-Akteurinnen und Akteure in Afrika zwar über starke Kompetenzen im Risikomangement verfügen, es jedoch deutliche Defizite bei der Einführung innovativer Strategien und Technologien zur Risikominderung gibt. Zudem wird die Vorbereitung auf Katastrophen stark von der Gefahrenexposition, der Risikowahrnehmung und der Verfügbarkeit von Ressourcen beeinflusst.

Diese Arbeit unterstreicht die dringende Notwendigkeit umfassender politischer Veräderungen um miteinander verbundene Treiber des sozialen Katastrophenrisikos in Afrika zu untersuchen und drohende Gefahren für die vielen Welterbestätten innerhalb der Katastrophen-Hotspots zu bewältigen. Sie hebt auch Kapazitätsdefizite unter den UNESCO-Akteurinnen und Akteuren hervor und zeigt die Bedeutung maßgeschneiderter Trainingsprogramme zur Verbesserung der Wirksamkeit des Risikomanagements. Die Ergebnisse dieser Studie tragen bei zur Verringerung der Risikoexposition des Welterbes in Afrika, Förderung der Widerstandsfähigkeit und der Sicherung einer nachhaltigen Zukunftsperspektive.

Declaration

I, **Emmanuel Eze**, declare that this thesis is the result of my original work and that it has not been previously presented, nor will it be presented in parts or whole, to any other university for a similar degree award or any other degree award. All portions and ideas derived from external sources have been duly identified and referenced in this thesis.

I conceptualised the research after two rounds of meetings with my supervisor, Professor Dr Alexander Siegmund. Subsequently, I initiated and conducted all the studies whose outcomes are presented in this document. This included designing the surveys, conducting interviews, gathering, and analyzing secondary data, interpreting all collected data, drafting the manuscripts, and undertaking all necessary editorial revisions until the final publication. Dr Maike Petersen helped me with the translation of the German abstract, which Ms. Franziska Wankmüller also checked.

Heidelberg, 29.07.2024

Publications

This thesis is based on six scientific publications in reputable journals. Indexes below are as of 10.06.2024.

Publication 1

Eze, E., & Siegmund, A. (2024a). Identifying disaster risk factors and hotspots in Africa from spatiotemporal decadal analyses using INFORM data for risk reduction and sustainable development. *Sustainable Development*, 1–22. https://doi.org/10.1002/sd.2886

Status: Published, 2024, Q1 SCImago Journal Rank, Impact factor: 12.5

Publication 2

Eze, E., & Siegmund, A. (2024b). Analyzing important disaster risk factors for enhanced policy responses in perceived at-most-risk African countries. *Environments*, 11(2):27. https://doi.org/10.3390/environments11020027

Status: Published, 2024, Q1 SCImago Journal Rank, Impact factor: 3.7

Publication 3

Eze, E., & Siegmund, A. (2024c). Next-generation core competency gaps for disaster risk management and preparedness in UNESCO-designated heritage sites. *Sustainable Futures.* 8 (100239), 11, https://doi.org/10.1016/j.sftr.2024.100239

Status: Published, 2024, Q1 SCImago Journal Rank, Impact factor: 5.5

Publication 4

Eze, E., & Siegmund, A. (2024d). Appraising competency gaps among UNESCO-designated heritage site actors in disaster risk reduction innovations. *Progress in Disaster Science,* 22 (100321), 9. https://doi.org/10.1016/j.pdisas.2024.100321

Status: Published, 2024, Q1 SCImago Journal Rank, Impact factor: 6.3

Publication 5

Eze, E., & Siegmund, A. (2024e). Exploring factors of disaster preparedness in UNESCO-designated heritage sites. *Geography and Sustainability.* 5 (3), 392-404. https://doi.org/10.1016/j.geosus.2024.04.001

Status: Published, 2024, Q1 SCImago Journal Rank, Impact factor: 9.7

Publication 6

Eze, E., Petersen, M. & Siegmund, A. (2024). Enhancing protection motivation for disaster preparedness among actors at UNESCO-designated heritage sites in Africa. *International Journal of Disaster Risk Reduction,* 109 (104599). https://doi.org/10.1016/j.ijdrr.2024.104599

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Part I: Synopsis

1

"Disasters are called natural as if nature were the executioner and not the victim." ~ Eduardo Galeano

I.1. Introduction

Disasters constitute an ongoing threat to communities and ecosystems globally. The recent report of Mizutori and Guha-Sapir (2020) underscores this reality, revealing a nearly 75 % increase in the frequency of disaster events between 2000 and 2019, which have affected over four billion people, and resulted in economic losses of almost three trillion dollars. Given the comprehensive impact of these threats across all spheres of nature, there is a pressing need for continuous systematic inquiries such as this thesis to inform policy and practice. Interestingly, as described by Scott (2020) and reiterated by Le Dé and Gaillard (2022), two worldviews exist in the disaster literature–the hazard and the vulnerability perspectives.

The hazard perspective offers a foundational understanding of disasters, with natural hazards considered the primary driver of disasters. However, this perspective often results in the separation of natural-hazard-induced disasters from their social contexts. The insufficient considerations of such factors as exposure and vulnerability by this perspective fosters what Scott (2020) describes as the uncritical usage of the term "natural disaster". In contrast, according to Gaillard (2019), the last four decades have recorded the revolutionary vulnerability perspective, which has emerged and expanded. A significant impact of this transformative shift is the recognition of the sociopolitical dimensions, and the widespread rejection of the term "natural disaster" (Gaillard, 2019).

Recently, van Riet (2021) referred to both disaster perspectives as a nature-culture distinction, which separates natural phenomena (nature) from human activities and social structures (culture). Such dichotomous thinking oversimplifies the disaster concept, ignores its multifaceted dynamics, and restricts management options. Hence, van Riet (2021) argues for the recognition of the complexity and interconnectedness of our world, while cautioning against uniformity in our approaches. Similarly, Chmutina and Von Meding (2019) echo the sentiment of adopting a nuanced approach to conceptualizing disasters, starting from differentiating between hazards and disasters, while they explain disasters as processes of maldevelopment. Within this study, the definition of key concepts of disasters provided by The United Nations General Assembly UNGA (2016) is adopted. This choice ensures alignment with the global common understanding and usage of these concepts by the public, authorities, and practitioners.

Hazards comprise distinct occurrences, whether originating from nature or human activity, with the potential to cause adverse socioeconomic and environmental consequences, such as loss of life or injury (UNGA, 2016). In contrast, disasters emerge as major disruptions within a community or society, resulting from the interplay of hazardous events, exposure, vulnerability, and coping capacity (UNGA, 2016). Accordingly, Rahman and Fang (2019) suggest that effective mitigation efforts must be necessitated by comprehending all these disaster elements.

As natural hazards themselves cannot be controlled, the focus of this thesis leans towards highlighting the manageable aspects of disasters, specifically vulnerability and coping capacity, while accounting for the frequency and influences of hazards. Vulnerability refers to the susceptibility of individuals, communities, assets, or systems to the impacts of hazards, influenced by various physical, social, economic, and environmental factors. At the same time, capacity encompasses the collective strengths, resources, and attributes available within an organization, community, or society to manage and reduce disaster risks effectively, enhancing resilience (UNGA, 2016).

Consequently, the thesis embodies two key aspects namely disaster risk assessment and capacity assessment, aiming to provide initial insights into the exposure levels of African heritage sites to disaster risk hotspots and the capacities for disaster risk management held by actors within these sites. Disaster risk assessment, as outlined by UNGA (2016), involves either/both qualitative and quantitative analyses of potential hazards, exposure, and vulnerability to determine the nature and extent of risk to people, property, livelihoods, and the environment. The disaster risk assessment in this study identifies hazards. It analyzes their technical characteristics such as location and intensity, while evaluating exposure and vulnerability levels across various dimensions including physical, social, health, environmental, and economic.

On the other hand, capacity assessment within the context of disasters as described by the UNGA (2016) entails evaluating the strengths, attributes, and available resources of a group, organization, or society against predefined goals. This process reveals existing capacities that require maintenance or improvement, and capacity gaps that necessitate further action to address. Over time, ongoing efforts to enhance capacity will lead to capacity development, contributing to the overall resilience and effectiveness of disaster risk management efforts (UNGA, 2016). The geographical scope of this disaster risk and capacity assessment is delimited to Africa and its heritage sites.

Heritage sites are invaluable cultural or natural elements, either in tangible or intangible forms, inherited from past generations. Lowenthal (2013) recognises the unequal values of heritages, even as precious and irreplaceable assets, crucial for both personal and collective identity, and essential for maintaining self-esteem. Hence, the study focuses specifically on UNESCO-designated heritage sites renowned for their outstanding universal values. These sites, collectively regarded as heritage sites in this thesis, include Global Geoparks (GGs), Biosphere Reserves (BRs), and World Heritage Properties (WHPs), which serve as vital centres for education and research. According to Pavlova et al. (2019), each site boasts unique geological formations, biodiverse landscapes, and exceptional cultural or historical significance. These UNESCO-designated sites play pivotal roles in conserving nature and safeguarding cultural heritage, offering opportunities to deepen our connection with history while promoting sustainable development.

As Aliyu (2015) noted, Africa is experiencing an increasing prevalence of natural and human-induced hazards. These hazards often lead to disastrous consequences such as loss of lives and livelihoods due to the vulnerability and inadequate coping capacity of societies and systems, as Raju et al. (2022) highlighted. Recently, Bari and Dessus (2022) identified 13 African countries among the 15 most vulnerable globally, with worsening poverty attributed to floods and droughts. Additionally, Koudjom et al. (2022) allude to the prevalence of informal economies in African countries, combined with a lack of social protection, which left households vulnerable to external shocks such as the recent COVID-19 pandemic, resulting in income losses, business closures, and household poverty. These studies paint a concerning picture of rising vulnerabilities across the region, present a perturbing outlook for valuable heritage sites in Africa and underlie the need for deeper exploration, and understanding of the interconnected elements of disasters in Africa.

The contributions of this thesis and its accompanying scientific publications aim to support the development of tailored disaster risk management strategies based on disaster risk drivers and hotspots identified from a decadal analysis and the capacity gaps of crucial actors. Disaster risk management, as defined by the United Nations General Assembly (UNGA, 2016), involves the implementation of policies and strategies to prevent new disasters, reduce existing risks, and manage residual risks, corresponding to prospective, corrective, and compensatory measures ultimately enhancing resilience and reducing losses in the event of hazard occurrence. These management strategies are commonly organized into a four-phase cycle in disaster literature. Tay et al. (2022) recently described these phases as mitigation, which aims to reduce disaster impact; preparedness, focusing on building response capacity; response, which coordinates immediate life-saving actions during a hazardous event; and recovery, aimed at restoring infrastructure and supporting affected communities.

The two key aspects pursued within the context of this thesis (i.e., disaster risk assessment and capacity assessment) seamlessly align with the three dimensions of prospective, corrective, and compensatory disaster risk management as outlined by UNGA (2016). For instance, the assessment of trends, patterns, factors, and hotspots of disaster risks and heritage site exposure provides outputs that could inform the reduction of current disaster risk (corrective management) and prevent new risks (prospective management) by addressing identified risk factors within the coping capacity and vulnerability components of risk (compensatory management). Moreover, an initial policy assessment focusing on the ten at-most-risk African countries is useful to address all three disaster risk management measures.

Similarly, the capacity assessment component of this thesis was conducted through a survey and interview of key actors within heritage sites, also called UNESCO actors. Here, potential risks likely to occur in heritage sites, which can be managed prospectively are identified. Also, insights into elements at most significant risk within these sites and resource and competency gaps for risk response and reduction offer corrective disaster risk management opportunities when implemented. Finally, the outcomes of preparedness assessments for the actors and the sites in the face of frequent hazards pave the way for targeted capacity building for resilience in line with compensatory disaster risk management principles.

Moreover, this thesis partly aligns with the paradigm shift in disaster studies advocated in a petition initiated by Gaillard et al. (2019), which advocates for a greater focus on local expertise and perspectives, and acknowledging the capacities inherent within local communities. By endorsing this petition along with over 650 scholars worldwide, the author of this thesis aligns with the overarching goal of generating research outputs that are more accurate, inclusive, accessible, and beneficial to all studied stakeholders. Hence, the choice of a suitable research approach and methodology to generate a combination of objective and subjective data for more robust outcomes.

In the subsequent sections of this introduction, the thesis aims and research questions are outlined and depicted in Figure I.1–1. The connection between the Sendai Framework for Disaster Risk Reduction and the objectives of the thesis is elucidated, followed by an introduction to the accompanying scientific papers. Subsequently, Chapter 2 conceptualises disaster risk assessment, while Chapter 3 focuses on capacity assessment. The research methods employed for this thesis are detailed in Chapter 4, and Chapter 5 presents the findings and key contributions of this thesis. Finally, Chapter 6 provides a synthesis of the key findings and major conclusions (Figure I.1–1).

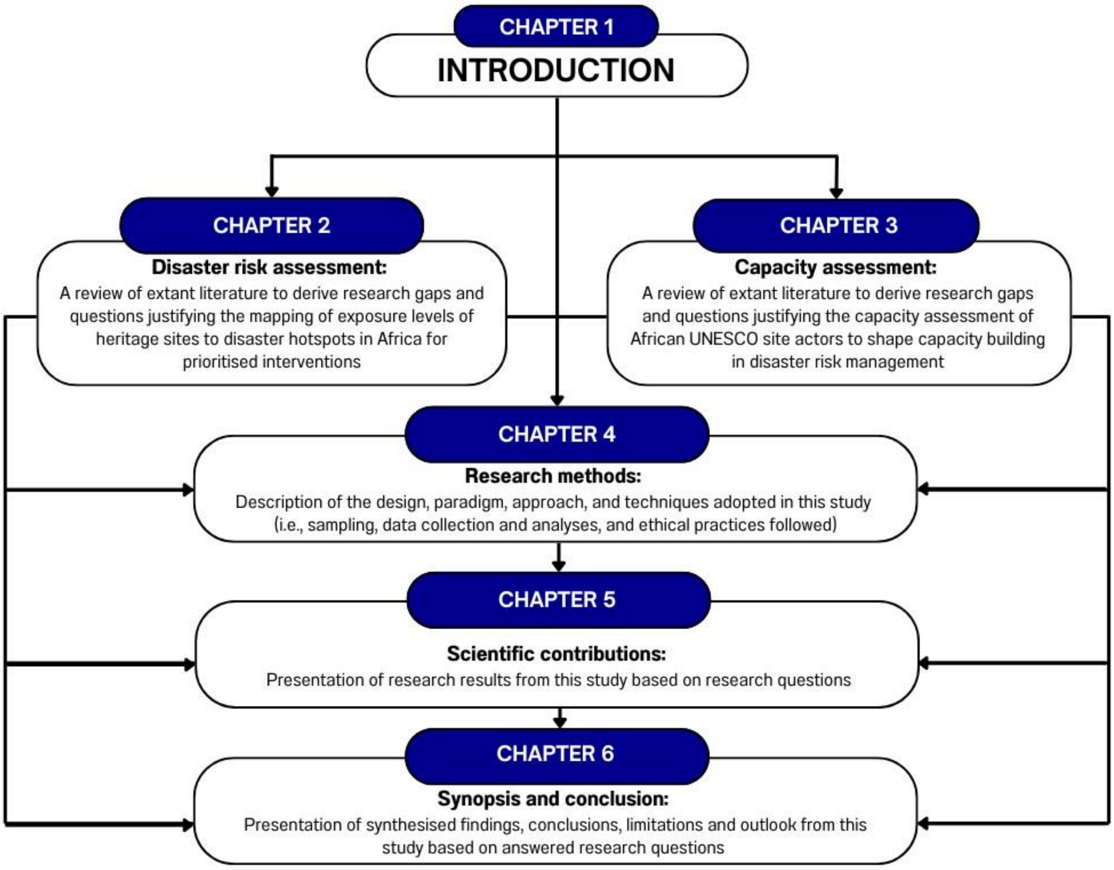

Figure I.1–1: Thesis structure

I.1.2. Research aims and questions

This thesis aims to enhance the understanding of disaster risks in Africa and the capacity gaps required for their management, particularly within UNESCO-designated heritage sites (also referred to as heritage sites throughout Section I of this thesis). This aim is achieved through a comprehensive disaster risk and capacity assessment, which demonstrates risk exposure levels and current capacity levels and gaps necessary for targeted and sustainable disaster risk management, and conservation of our collective heritage.

Therefore, the thesis addresses two overarching questions with seven sub-questions:

1. What is the level of exposure of heritage sites to disaster hotspots in Africa?
   1.1. What are the trends, patterns, and factors of disaster risks in Africa?
   1.2. How are heritage sites distributed within disaster risk hotspots in Africa?
   1.3. What is the level of inclusion of disaster risk drivers within core policy frameworks of the at-most-risk African countries?
2. What is the capacity level of African UNESCO site actors for disaster risk management?

2.1. What are the next-generation core competencies in disaster risk management possessed by UNESCO site actors?
2.2. What are the capacity gaps in disaster risk reduction innovation among UNESCO site actors?
2.3. What factors influence disaster preparedness in UNESCO-designated heritage sites?
2.4. What is the protection motivation of African UNESCO site actors for disaster preparedness and heritage conservation?

I.1.3. Thesis Intersection with the Sendai Framework for Disaster Risk Reduction

The Sendai Framework for Disaster Risk Reduction is a global policy of the United Nations aimed at significantly reducing disaster risks and losses by 2030. It outlines four priority areas: understanding disaster risk in its multi-dimensional nature, strengthening disaster risk governance at all levels, investing in disaster risk reduction for resilience, and enhancing disaster preparedness for effective response and recovery (United Nations International Strategy for Disaster Reduction (UNISDR, 2015)). The framework emphasizes the importance of characterizing disaster risk drivers and calls for sustainable support, including finance, technology transfer, and capacity building from developed countries tailored to the needs and priorities of developing countries.

The research questions addressed in this thesis intersect with several aspects of all four priorities outlined in the United Nations Sendai Framework for Disaster Risk Reduction (UNISDR, 2015). Figure I.1–2 provides a visual representation of how each research question and its outcomes align with specific actions outlined in the Sendai Framework. These connections underscore the thorough exploration of the topic within this thesis, with the findings offering crucial insights to address capacity gaps for disaster risk reduction within African heritage sites.

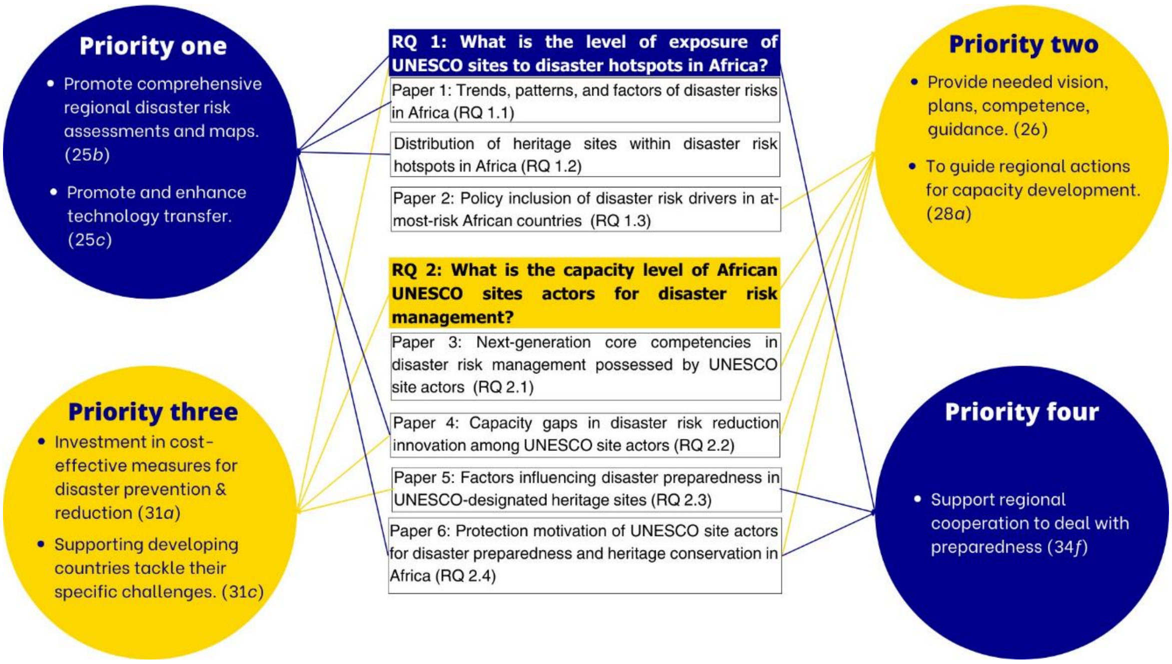

Figure I.1–2: Connections of thesis objectives with the Sendai Framework
Notes:
RQ 1.1. = Research question number within the thesis
25*b* = Paragraph and section number within the Sendai Framework

The research objectives of this thesis align seamlessly with relevant sections of the Sendai Framework. For instance, the first objective addressed by RQ 1, which involves conducting a comprehensive disaster risk and policy assessment for Africa, corresponds to paragraphs 25 (b), (c) and 31 (a). Similarly, the second objective within RQ 2, which assesses different dimensions of capacity, aligns with the call to facilitate technology transfer and capacity building in paragraphs 26, 28 (a), 31 (c), and 34 (f). These connections between the thesis objectives and the Sendai Framework demonstrate the academic contribution of providing a regional assessment of disaster risk factors and capacity assessment, bridging the gap between policy and science for decision-making.

I.1.4. Publication overview

This thesis comprises six scientific publications, each contributing to a comprehensive understanding of disaster risk exposure and management capacities within African UNESCO-designated heritage sites (Figure I.1–3). The author conducted all research independently, drafting manuscripts and overseeing the entire publication process.

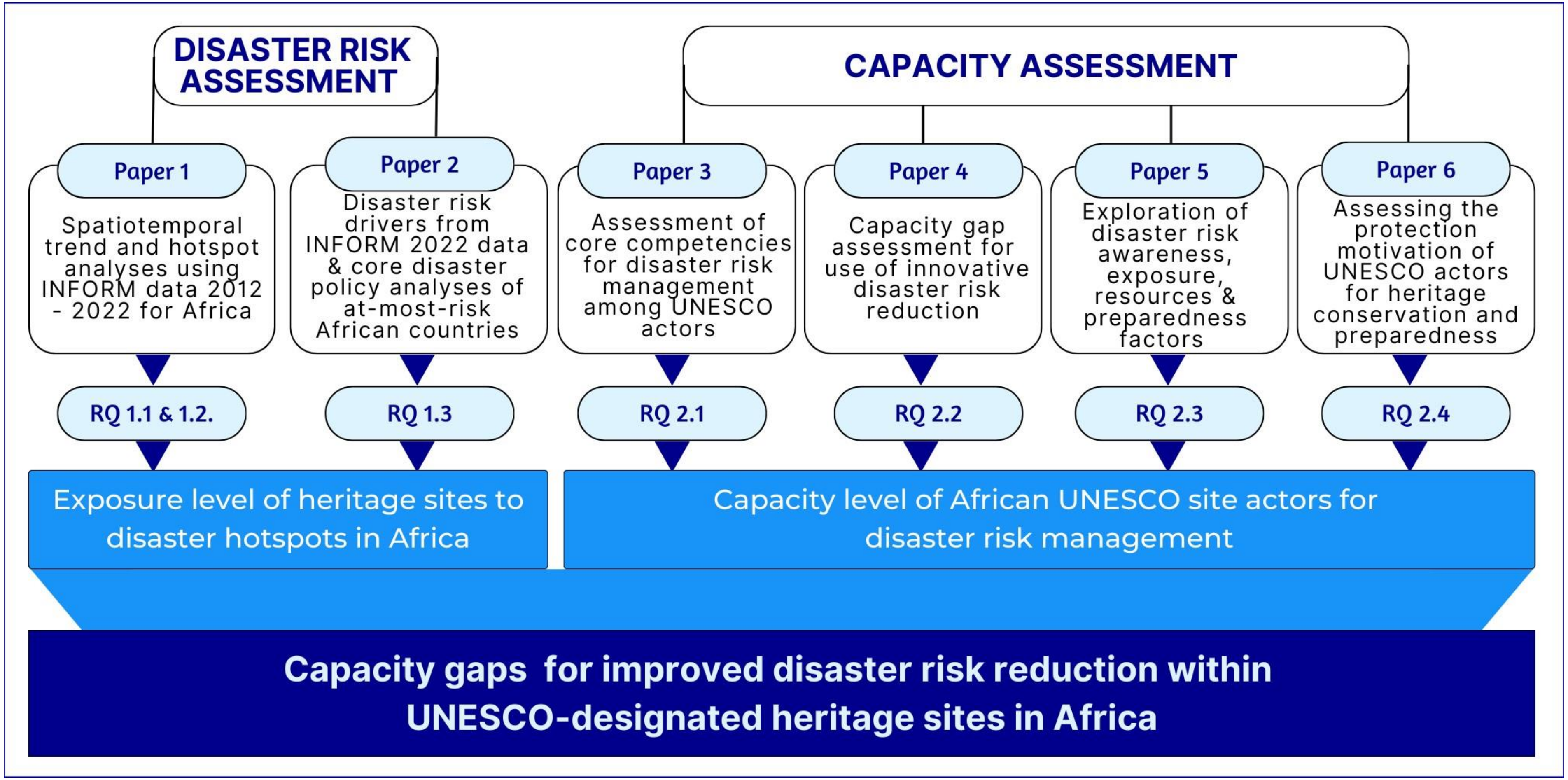

Figure I.1–3: Publications integrated in this thesis

Paper 1, detailed in Section II.1, explores Africa's disaster risk trends, patterns, factors, and hotspots through spatiotemporal decadal analyses using INFORM data from 2012 to 2022. From this paper, maps of the exposure levels of African heritage sites to hotspots were created, addressing RQ 1.1 and providing the foundation to answer RQ 1.2.

In Paper 2, presented in Section II.2, the focus shifts to including disaster risk drivers in core policies of the ten most at-risk African countries. The paper highlights the emphasis of policies on social vulnerabilities and the neglect of certain hazard drivers, notably human-induced hazards like violent conflicts, addressing RQ 1.3.

Paper 3, found in Section II.3, presents results from a global survey of UNESCO actors, examining next-generation core competency gaps in disaster risk management and their implications for preparedness within African heritage sites. This thesis focuses on responses from African actors to address RQ 2.1.

In **Paper 4** within Section II.4, the second part of the global survey is discussed, with a specific emphasis on competency gaps among UNESCO-designated heritage site actors in applying disaster risk reduction initiatives. Training needs are ranked by importance to the actors, with a closer examination of African data to answer RQ 2.2.

Paper 5, detailed in Section II.5, lays out factors influencing disaster preparedness in heritage sites, employing the Person-Relative-to-Event Model. Responses from African actors were extracted from this comprehensive analysis, to provide insights for targeted disaster risk management strategies and interventions, addressing RQ 2.4.

Lastly, **Paper 6** in Section II.6 reports findings from a qualitative study focused on African UNESCO actors, examining motivation for disaster preparedness through the lens of the Protection Motivation Theory. The study confirms and expands upon theoretical elements while offering additional insights grounded in empirical data, addressing RQ 2.4.

Having introduced the thesis, the next section highlights the significance of disaster risk assessment in understanding disaster risks within the context of the Sendai Framework for Disaster Risk Reduction.

2

"Preparation through education is less costly than *learning through tragedy."* ~ Max Mayfield

I.2. Disaster risk assessment

This chapter explores prior research on disaster risk assessment, identifying gaps and problems, and deriving relevant research questions addressed in this thesis.

In recent years, there has been a notable emergence of global indices designed to assess country-level disaster risks. These indices, as highlighted by Garschagen et al. (2021), play a crucial role in enhancing our understanding of disaster risk patterns, dynamics, and drivers, while also influencing policy formulation and financial decisions, particularly in allocating funds to vulnerable countries. The paramount importance of comprehending disaster risks is underscored by its placement as the top priority of the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015). Accordingly, the Sendai Framework advocates for disaster management policies and practices grounded in a comprehensive understanding of all dimensions of disaster risk, including vulnerability, hazard, exposure, and capacity.

Prior research works have comprehensively explored the significance of disaster risk assessments. For instance, Murnane et al. (2016) elucidate the pivotal role of risk assessments in supporting essential disaster risk management activities, which are further articulated by the five pillars outlined by Bello et al. (2021): risk identification, risk reduction, preparedness, financial protection, and resilient recovery. As such, the findings of disaster risk assessments serve as a robust foundation for the pillars of managing disaster risks. Additionally, Murnane et al. (2016) emphasize the necessity of clearly defining the purpose of the risk assessment from the outset. Hence, the objective of assessing disaster risks in this thesis is to enhance awareness of risk trends, and the exposure of heritage sites to hotspots, for stimulating informed decision-making towards implementing proactive risk reduction measures.

The initial attempt to conduct a global-scale risk assessment was a natural disaster hotspot analysis conducted by Dilley et al. (2005). Since then, scientific efforts to develop risk assessment methods for informed decision-making have continued (Ward et al., 2020). For example, Peduzzi et al. (2009); Welle and Birkmann (2015); Garschagen et al. (2016); Eckstein et al. (2018); and the European

Commission Joint Research Centre (ECJRC, 2023) developed global-scale disaster risk indexes combining different risk components. Further analyses using these indices are useful for identifying areas at risk to facilitate the effective deployment of tailored disaster risk reduction strategies (Ramli et al., 2021). Despite the advancements in developing standardized global indices, various studies, including those by Garschagen et al. (2021), Osuteye et al. (2017), and Panwar and Sen (2020), highlight ongoing challenges related to underreporting disaster impacts, the reliability of inputs, and the conceptual and methodological approaches used in constructing these indices. Therefore, it was essential to exercise caution in selecting an index for further analysis and interpreting the results.

Consequently, this thesis adopts the Index for Risk Management (INFORM) of the European Commission Joint Research Centre for analysis to depict the exposure levels of African UNESCO-designated sites to disaster risks. The INFORM model offers a comprehensive framework for risk assessment. The three crucial dimensions recommended by the Sendai Framework for Disaster Risk Reduction (i.e., hazards and exposure, vulnerability, and lack of coping capacity) are integrated into the development of the INFORM. An extended presentation of INFORM is contained in Section II.1.2.2. This model comprises 53 indicators and further aligns with the global initiative of advancing and achieving the Sustainable Development Goals (SDGs). Marin-Ferrer et al. (2017) describe INFORM as a pioneering global open-source tool, which is continually updated to provide an evidence-based approach to risk analysis.

The European Commission Joint Research Centre published a report by Thow et al. (2024) marking a decade of consistently delivering enhanced disaster risk data for 191 countries. Moreover, previous studies by Beccari (2016) and Visser et al. (2020) have compared the INFORM model against other disaster index modes. While Beccari (2016) recognizes INFORM as the most intricate model, Visser et al. (2020) highlight its robustness, validity, and reliability based on their performance evaluation criteria. These validation studies underline the preference for utilizing the INFORM model in this thesis as a credible tool for risk analysis and data-driven decision-making for DRM. Hence, the INFORM model serves as a valuable data source for the disaster risk assessment, aimed at identifying heritage sites exposed to disaster hotspots in Africa and addressing the first objective of this thesis.

As exemplified by Holloway (2012), previous research laments the dearth of robust, data-driven scholarship on disaster and risk management in Africa, citing constraints in human and financial resources, compounded by environmental and socioeconomic challenges. Fortunately, few studies have begun to address this gap. The recent continent-wide analysis of Bol and van Niekerk (2023) using century-long climate and hazard data reveals a concerning escalation in climate-related disasters across Africa, attributed in part to rising El Niño–Southern Oscillation (ENSO) episodes and exacerbated by rapid, unchecked urbanization. However, their study overlooks human-induced hazards and key vulnerability and coping capacity factors. Another study by Ahmadalipour and Moradkhani (2018) focused solely on Africa's vulnerability to historical and future droughts.

Remarkably, no study known to the author has comprehensively assessed trends, patterns, factors, and hotspots of disaster risks in Africa using long-term data. Drakes and Tate (2022) underscore the geographical limitations of existing research on social vulnerabilities in low-income nations, impeding an extensive identification of vulnerability factors. Moreover, Abdel Hamid et al. (2020) assert that limited resources and infrastructure hinder lower-income economies' ability to cope with hazards therefore resonates strongly. Thus, it is imperative to thoroughly examine disaster risk in Africa, particularly as a low-income and highly vulnerable region, to guide sustainable interventions aimed at reducing vulnerability and prioritising areas of higher disaster risks in allocating scarce resources for risk management.

Beyond understanding disaster risks, the significance of the comprehensive decadal disaster risk assessment conducted within this study is extended by mapping the location of heritage sites within disaster risk hotspots in Africa. Thus, the first research question addressed by this study **(RQ 1)** ensues: ***What is the level of exposure of UNESCO sites to disaster hotspots in Africa?*** Being a broad question, three sub-questions were further developed, namely: ***what are the trends, patterns, and factors of disaster risks in Africa?*** **(RQ 1.1.)**; ***how are heritage sites distributed within disaster risk hotspots in Africa?*** **(RQ 1.2.)**; ***and how do policy frameworks in the at-most-risk African countries include disaster risk drivers?*** **(RQ 1.3.).**

In addressing RQ 1 and its sub-questions, this study fulfils the requirement for a geographically comprehensive assessment of disaster vulnerability highlighted by Drakes and Tate (2022). It also offers a thorough and evidence-based disaster risk assessment for Africa, aligning with the recommendations of Holloway (2012). Furthermore, this study bridges conceptual gaps identified in previous research as presented in earlier sections, such as those observed in the works of Bol and van Niekerk (2023) and Ahmadalipour and Moradkhani (2018).

Following the identification of research gaps and questions in disaster risk assessment, which aim to enhance understanding of disaster risks and the exposure of heritage sites to hotspots in Africa, it is crucial to examine the capacity levels of actors managing these sites. Therefore, the next chapter focuses on literature shaping the capacity assessment within this study.

3

"To grow capacity in your career, you need to move from the place of position to a place of skill acquisition." ~ Olawale Daniel

I.3. Capacity assessment for disaster risk management

Chapter 2 describes the need for disaster risk assessment in Africa, culminating in mapping the exposure levels of heritage sites to disaster risk hotspots. This chapter discusses the evaluation of knowledge, competencies, and capabilities required to manage disaster risks at heritage sites. It also outlines research questions aimed at identifying capacity gaps among UNESCO actors.

Inherent in the concept of disaster are elements that depict both strengths (coping capacity) and weaknesses (hazards exposure and vulnerability). While disaster risk assessment described in Chapter 2 focuses on understanding the nature and extent of disaster risks, capacity assessment evaluates the resources and capabilities available to manage and reduce those risks. Both assessments are vital for developing tailored approaches for prospective, corrective, and compensatory disaster risk management. The earlier-presented definition of capacity assessments by UNGA (2016) shows that obtained results from measuring present capacity against desired capacity goals could provide insights into the strengths and available resources of a group, organization, or society against predefined goals, showing gaps that require improvement. Moreover, literature, including UNGA (2016) and Hagelsteen and Burke (2016) agree that adopting the results of capacity assessments in sustained capacity building will ultimately lead to capacity development, increased resilience, and reduction of disaster losses.

An examination of capacity assessment literature conducted by Ofei-Manu and Didham (2018) identifies six potential generic capacity gaps within disaster risk reduction systems: funding, knowledge, information communication, policy leadership, coordination, and balance gaps. This study specifically centres on knowledge gaps, defined by Ofei-Manu and Didham (2018) as 'insufficient knowledge and skills to understand the underlying risks of hazards/disasters; inadequate institutional and physical infrastructure (hardware), as well as human knowledge, expertise, and skills (software).' Furthermore, in agreement with Eze et al. (2022), identifying knowledge gaps represents a crucial initial step in designing tailored professional development initiatives for capacity building. These initiatives are essential for meeting the required capacity standards necessary for enhancing resilience to disasters. Hence the second overarching research question **(RQ 2)** answered by this study: ***What is the capacity level of African UNESCO site actors for disaster risk management?***

Therefore, this thesis reports the results of a capacity assessment unveiling knowledge gaps among UNESCO actors (including site managers, site staff, and members of UNESCO National Commissions in African countries). These actors come from diverse backgrounds and actively engage in the management and oversight of heritage sites. Other related concepts such as capability, and competency further shaped the study. From a synthesis of extant literature, Lindbom et al. (2015) identify capability as a construct that integrates resources, inherent ability and readiness to implement potential actions, which have significant impacts on achieving desired goals. Subsequently, Lindbom et al. (2018) insist that information regarding resources and tasks for disaster management must be elicited through comprehensive capability assessments to enhance utility by decision-makers in reducing disaster losses.

On the other hand, competency entails the fusion of knowledge, skills, and abilities essential for effective professional performance in real-life problem-solving and task execution scenarios (Wiek et al., 2011). A more structured framework of the concept of competency by Kaslow et al. (2018) assigns five dimensions: knowledge of concepts, skills, abilities, and behaviours; attitudes and beliefs; demographic and situational factors; and motivations. Thus, drawing from the three related concepts of capacity, capability and competence, this study assesses core competencies for disaster risk management, with the sub-research question: ***What are the next-generation core competencies in disaster risk management possessed by UNESCO site actors?*** **(RQ 2.1.)**. Feldmann-Jensen et al. (2019) developed a thorough framework comprising 13 "next-generation core competencies" to address the evolving environmental challenges anticipated beyond 2030. This study conducts a pioneering survey of these competencies among UNESCO actors, with forward-looking implications for the sustainability of heritage sites beyond the objectives outlined in the Sendai Framework for Disaster Risk Reduction, and Sustainable Development Goals targeted for 2030.

Previous studies by Manatsa and Sakala (2023), Orimoloye et al. (2021a), (2021b), and Hu et al. (2018) emphasize the crucial role of innovative technologies and approaches in mitigating disaster risks. The ever-evolving landscape of science and technology, as discussed by Shaw (2020), emphasizes the necessity of continuous adaptation to innovative technologies. Moreover, Ofli and Imran (2023) draw attention to the transformative impact of Artificial Intelligence (AI) on Disaster Risk Reduction, while Shaw et al. (2018) connect the successful adoption of innovation in implementing the Sendai Framework with prioritising field needs. Therefore, a list of innovative technologies and approaches for disaster risk reduction produced by Izumi et al. (2019) was used to conduct a capacity needs assessment in this study in answer to another sub-research question **(RQ 2.2.)**: ***What are the capacity gaps in disaster risk reduction innovation among UNESCO site actors?*** The study appraises the perceived importance and experience levels of African UNESCO actors to derive the capacity gaps to be enhanced. As an initial needs assessment, the study lays a groundwork for future research and offers a basis for designing immediate and tailored capacity-building programs to address the identified and prioritised capacity gaps.

Furthermore, the alarming exposure levels of 92 % of global UNESCO-designated heritage sites to various hazards threatening their sustenance as captured by Pavlova et al. (2017) and Pavlova et al. (2021) warranted a close inquiry into the disaster preparedness status of these sites. In addition, Shi et al. (2020) rank disaster preparedness as the most important of the four stages of disaster risk management since preparedness covers key elements such as capacity building, disaster response schemes, communication, and education. Therefore, in the context of this study and guided by the Person-relative-to-Event model of Duval and Mulilis (1999), a sub-research question **(RQ 2.3.)** was posed: ***What factors influence disaster preparedness in UNESCO-designated heritage sites?*** To respond to the question, concepts such as disaster exposure, risk and vulnerability perception, available resources, disaster experience, disaster awareness, and their influence on disaster preparedness were assessed.

In addition, to capture the motivation dimension of competency as documented by Kaslow et al. (2018), the basic Protection Motivation Theory by Rogers (1975) was followed. The theory suggests that an individual's motivation to protect themselves is based on how they perceive a threat and their ability to cope with it. Applying the theory to this study's context, a presumption was made that UNESCO actors are motivated to protect heritage sites and prepare for disasters if they perceive their coping (risk management) levels to be higher than the threats (of hazards and disasters). Thus, the last sub-research question **(RQ 2.4)** of this study is: ***What is the protection motivation of African UNESCO site actors for disaster preparedness and heritage conservation?*** Measuring motivation for heritage conservation and disaster preparedness as a competency dimension in this study offers an opportunity to examine (non) supporting factors of motivation through the lens of the protection motivation theory. Additionally, data-driven insights from interviews with African UNESCO actors complement this approach for contextual contributions.

In addressing the sub-questions of RQ 2, this study offers a comprehensive insight into the capacity levels and deficiencies among African UNESCO actors in mitigating the risks faced by heritage sites. By uncovering core competency levels, capacity gaps, and motivations for heritage conservation, the research provides a basis for developing targeted capacity-building initiatives. Such initiatives are essential for addressing identified gaps from this study, effectively confronting the complex challenges posed by disasters, and ensuring the preservation of our collective heritage for both present and future generations.

Here in Chapter 3, this thesis delineated the various dimensions and components of capacity that are to be assessed, building upon the groundwork laid out in Chapter 2, which covered aspects of disaster risk assessment. Moving forward, the subsequent chapter outlines the methodologies employed in conducting this research.

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“More exploratory research could be recognized as ‘cutting-edge’ if it were breaking open new questions through identification of novel patterns or processes.” ~ Evan Lieberman

I.4. Research methods

This chapter outlines the design, paradigm, and methodological approaches employed in the research within this thesis, aiming to crystalize the foundational principles guiding the methodological decisions, including sampling, data collection, and analytical techniques.

I.4.1. Research design

A research design is defined by Ranganathan and Aggarwal (2020) as a structured plan that outlines the methods and procedures for collecting and analyzing data based on the research problem, objectives, and questions, as well as the available resources at the researcher's disposal. This study adopts an exploratory research design. According to Swedberg (2020), exploratory studies involve a systematic multi-method inquiry into previously unexplored topics or the examination of existing topics to generate fresh ideas and hypotheses with limited possibilities for representative sampling or validation.

Due to the preliminary nature of this study, the exploratory research design is considered suitable for its ability to provide initial insights into the exposure levels of heritage sites to disaster risk hotspots in Africa and the capacity levels of actors within these sites for disaster risk management. The diverse range of data collection and analytical methods employed in this thesis aligns with the multi-method nature of exploratory research, making it a suitable choice for addressing the research questions. Therefore, the author adopts an exploratory research design to lay the groundwork for further in-depth studies and validation in the future.

I.4.2. Research paradigm

Adopting a research paradigm enhances the credibility of a study, and Kankam (2019) attributes the choice of paradigms to the preferences of researchers based on the nature of the phenomenon being studied. Kuhn (1970), who introduced the term "paradigm," describes it as an integrated set of concepts, variables, and problems, underpinned by consistent methodological approaches and tools. Three key paradigms are commonly used in research: interpretivism, positivism, and pragmatism.

Interpretivism recognizes the social construction of reality and focuses on understanding the meanings and experiences of individuals or groups from their perspectives (Mahadevan, 2023). It employs qualitative methods such as interviews and focus groups to provide a contextual understanding of phenomena. Conversely, positivism assumes that reality is objectively measurable and quantifiable, utilizing quantitative methods such as surveys, experiments, and statistical analyses to test hypotheses and develop theories (Mahadevan, 2023). For this research which sought to identify capacity gaps within heritage sites in Africa, relying solely on objective quantitative measures (positivism) or exclusively seeking qualitative contextual meanings (interpretivism) would be insufficient.

Therefore, the unique nature of this topic necessitates a combination of interpretivism and positivism, known as pragmatism. This pragmatic approach allows for the objective measurement of specific constructs while also incorporating the contextual understanding of phenomena. According to Dawadi et al. (2021), the pragmatic research paradigm values both objective and subjective/contextual knowledge and combines multiple methods to meet research objectives. Moreover, Creswell and Poth (2016) highlight the flexibility of pragmatism, allowing researchers to select methods or strategies that best address their research questions, which further justifies its choice for this study. Hence, the collection and integration of quantitative and qualitative data were carefully implemented to ensure that the study provides a comprehensive view of relevant information to uncover both objective and contextual insights making it highly relevant for policy and practical applications, and social changes in disaster risk management within heritage sites in Africa.

This study was also influenced by contemporary geographical paradigms known as systems thinking and choroinformatics, as proposed by Dasgupta and Patel (2017), and Koutsopoulos (2011) respectively. Dasgupta and Patel (2017) argue that systems thinking prevents the undervaluation of either physical or human elements within geographic space, offering a comprehensive understanding of global challenges like environmental degradation and climate-induced disasters. Similarly, Koutsopoulos (2011) describes choroinformatics as a method that considers ecological, economic, social, political, and cultural aspects to address complex societal problems. Thus, the adoption of such a paradigm is considered crucial for enhancing disaster risk management in this study. Consequently, the integrated assessment of both natural and human-induced hazards, along with socioeconomic and anthropological variables within this thesis, aligns with contemporary geographic research methods.

I.4.3. Research approach

The author employed a mixed methods approach for this study, integrating both qualitative and quantitative methodologies. Here, a mixed methods research approach was used, adopting different data collection and analysis techniques, which Creswell and Creswell (2017) argue will leverage the strengths of both approaches for a more robust study outcome. The qualitative research approach involves iterative questioning and data collection in natural settings, with inductive analysis to understand the meanings attributed to human or social issues. In contrast, the quantitative research approach focuses on collecting and statistically measuring numerical data based on variables of interest, using prescribed instruments, and deductively testing theories derived from previous research (Creswell & Creswell, 2017).

In this thesis, a blend of inductive and deductive approaches was utilized to identify capacity-building needs for enhancing disaster risk management within African heritage sites. Haque (2022) advises researchers to decide at the outset whether to use a deductive or inductive approach. The author defines the deductive approach as testing an existing theory by forming hypotheses and designing a research plan to examine them, while the inductive approach involves collecting data first and then developing a theory based on the findings. In this study, the Person-Relative-to-Event model was employed deductively to address RQ 2.3. following a top-to-bottom style (i.e., starting with theory and proceeding to participants' views). Similarly, the Protection Motivation Theory (PMT) was deductively used in designing the study answering RQ 2.4., however, participants' responses provided inductive inputs outside of the PMT, thus extending its concepts.

Additionally, the research papers informing this thesis integrated qualitative and quantitative methodologies in two ways. Firstly, an embedded survey approach collected quantitative data while allowing for qualitative insights through open-ended items for studies presented in Paper 3, Paper 4, and Paper 5 respectively reproduced in Sections II.3, II.4 and II.5. Secondly, qualitative and quantitative outcomes converged in joint displays in Table I.5–4 and Table I.5–10. Hence, this thesis responds to the recommendations of Creswell (2014) and Dawadi et al. (2021) preferring mixed methods research to enhance the credibility and comprehensiveness of exploratory research findings.

I.4.4. Sampling

The aim of this study was not to present representative results generalisable to the entire African continent but to obtain initial insights into disaster risk exposure of heritage sites and the capacity of actors within these sites, which are unavailable from previous studies. Therefore, a non-probabilistic purposive sampling technique was used, targeting relevant disaster and climate change adaptation policy documents and African UNESCO actors to answer the preset research questions in this study. In line with the description of explorative studies by Swedberg (2020), this sampling approach allowed for the combination of various purposeful sampling techniques, drawing from the supporting literature.

For the policy analyses within this thesis in answer to RQ. 1.2. key policy documents were selected such as national disaster risk management policies, Nationally Determined Contributions (NDCs) submitted to the United Nations Framework Convention on Climate Change (UNFCCC), and National Adaptation Programmes of Action for Climate Change (NAPAs). These documents, as described in the subsequent section, are considered by scholars such as Zhu and Shang (2024) and Holvoet and Inberg (2014) as fundamental in the context of disaster risk management, climate change adaptation and mitigation.

In conducting the survey addressing RQ 2.1., RQ 2.2., RQ 2.3. and the interviews for RQ 2.4., a combined approach of harvested email lists Fricker (2008) and river sampling Lehdonvirta et al. (2021) was employed, both categorized under convenience non-probability sampling. Harvested email lists were compiled from various online platforms, while river sampling involved inviting UNESCO actors, who are preferred respondents to participate in the study through the links sent to their emails. The survey was initially distributed to 1,009 email addresses of UNESCO actors worldwide, with 264 affiliated with African sites. Despite reminders, the response rate from African UNESCO actors remained at 11 %, with 28 completed surveys.

Similarly, for the interviews conducted to address RQ 2.4., the same combined approach of harvested email lists and river sampling was utilized. However, the number of participants was determined based on achieving data saturation, a criterion for discontinuing data collection in qualitative research (Saunders et al., 2018). Saturation was achieved both in terms of data and thematic saturation, as no new themes emerged during the analysis process, and the final two interviews did not yield additional insights. A total of 21 UNESCO actors from nine African countries participated in the interviews, covering multiple sites across Central, Eastern, Western, and Southern Africa.

I.4.5. Data collection

This thesis was developed using a combination of primary and secondary data, incorporating both quantitative and qualitative typologies. They are presented below.

The Index for Risk Management (INFORM) risk data

The study extracted component- and category-level data for analysis from the INFORM risk model output for the year 2023, sourced from https://drmkc.jrc.ec.europa.eu/inform-index/. This dataset covers the period from 2012 to 2022 and consists of 29 variables per annum. The overall risk index of the INFORM model was used as the dependent variable for the relevant quantitative analyses conducted in this study to address RQ 1.1., extract information to answer RQ 1.3. and ultimately depict the exposure of African heritage sites to disaster risk hotspots.

The preference for using the INFORM data in this thesis is supported by previous studies, including Egawa et al. (2018) and Birkmann et al. (2022), which demonstrate the comprehensiveness, validity, and reliability of the INFORM data for disaster risk assessment. Furthermore, the continuous availability of the INFORM data was advantageous for conducting a decadal spatiotemporal disaster risk assessment and hotspot mapping.

Core policies of at-most-risk countries

Documents comprising disaster risk reduction policies, Nationally Determined Contributions (NDCs), and National Adaptation Programmes of Action for Climate Change (NAPAs) were analysed in this study. Collectively referred to as core policies, these documents are deemed reliable and appropriate for assessing their coverage of disaster risk drivers in response to RQ 1.2., as they are published by national agencies of the respective countries following global frameworks. Previous studies have highlighted the importance of these core policy documents for assessments, similar to the one conducted in this thesis.

For example, the NDCs are critical climate policy documents created by countries under the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement, aimed at delineating their objectives for mitigating national emissions and adapting to climate change impacts. Zhu and Shang (2024) identify the assessment of NDCs as an emerging field of study, noting a significant research gap in the specific examination of African countries' NDCs. This gap results in their perspectives and positions being underrepresented in global climate negotiations. Similarly, NAPAs, according to Holvoet and Inberg (2014), are policy documents prepared by countries most vulnerable to climate change, identifying specific and prioritized adaptation projects to address their urgent needs.

Survey data

An online survey comprising 35 broad items attached as Appendix 1 was created by the researcher and disseminated globally through SurveyMonkey. The survey sought responses regarding next-generation core competencies in disaster risk management, experience with innovative disaster risk reduction approaches, and disaster-related concepts and preparedness. Respondents provided anonymous feedback using Likert-type scales, Yes/No responses, checklists, and open-ended questions, which yielded mostly quantitative data. The responses of 28 African UNESCO actors were extracted from the global survey to provide the primary data analysed for answering RQ 2.1., RQ 2.2., and RQ 2.3. of this thesis.

Interview data

A semi-structured interview guide, as detailed in Table II.6–2, was employed to elicit open-ended responses from UNESCO actors regarding the elements of the protection motivation theory to correspond to RQ 2.4. These interviews generated rich qualitative data, with participants providing insights during discussions that were recorded. In total, approximately 1,504 minutes of recorded content were collected, with individual interviews ranging from 20 to 75 minutes and averaging 52 minutes in duration. Prior consent was obtained for recording the interviews, and to ensure confidentiality, transcripts were anonymized by removing any identifiable information and assigning numerical identifiers based on the sequence of the interviews.

I.4.6. Data analyses

The author employed a diverse array of analytical techniques to extract meaningful insights from the collected data and address the predetermined research questions. To explore RQ 1.1., a combination of analytical methods was applied to the INFORM data from 2012 to 2022, including trend analyses, random forest regression, variable importance analyses, spatial stratified heterogeneity, and hotspot analyses. These approaches were chosen to elucidate the intricate patterns, trends, and interactions among various factors influencing disaster risks in Africa. The overarching goal was to identify UNESCO-designated sites situated in regions characterized by heightened risk levels, thereby highlighting areas in need of prioritized attention and intervention. A comprehensive overview of these analytical methodologies is provided in Section II.1.3.3.

Additionally, three techniques were applied to evaluate the extent to which core policies of at-most-risk countries in Africa address disaster risk drivers, as outlined in response to RQ 1.2. Initially, random forest regression and variable importance analyses were conducted on INFORM data for the year 2022 to identify prominent disaster risk drivers. Subsequently, a summative content analysis approach, inspired by Hsieh and Shannon (2005), was utilized. This method involves tallying specific keywords or concepts found within the selected policy documents to extract contextual insights. To ensure the reliability of the findings, an independent reviewer assessed the results, resulting in an inter-rater coding agreement of approximately 91%. For more detailed information, please refer to Section II.2.3.2.2.

To answer RQ 2.1., RQ 2.2., and RQ 2.3., survey data from African respondents was extracted from the global survey and analyzed. The results of the global analyses are presented in Section II.3, Section II.4, and Section II.5, corresponding to Eze and Siegmund (2024ec), (2024bd), and (2024ce). Percentages, crosstabulation, and means were used to describe the rated responses to various concepts tested, as reported in Section I.5. Additionally, the mean weighted discrepancy score (MWDS) and ranked discrepancy score (RDS) presented in detail in Section II.4.1.2 and Section II.4.2.4 were utilized to evaluate the capacity-building needs of African UNESCO actors regarding innovative disaster risk reduction technology and approaches.

Due to the limited sample size, advanced analyses such as principal component analyses, regression, and cluster analyses, which were performed for the global survey data in the published papers could not be conducted for the African data. However, crosstabulation was adopted to evaluate factors of disaster preparedness in place of regression analyses. Furthermore, cluster membership of African UNESCO actors was extracted from the analyzed global survey results to show the combination of disaster risk management core competency levels possessed and site preparedness.

Interview data collected to address RQ 2.4. underwent analysis using a deductive-inductive approach. According to Armat et al. (2018), this method combines deduction, primarily guided by an existing theory (in this case, the protection motivation theory), with induction, where new categories emerge from the data itself. This study initially framed its analysis based on the protection motivation theory, utilizing its predefined categories and factors. However, during the analysis process, additional categories emerged from the interview data, complementing those imposed by the theory. As a result, the study confirmed (non-)contributing factors to protection motivation and disaster preparedness both from the theory and from new insights gleaned from the interview data.

I.4.7. Ethical practices

The initial study conducted for this thesis, as detailed in Sections II.1 and Section II.2, focused on disaster risk and policy assessment and did not involve human participants or animals. Therefore, ethical clearance was not required for this aspect of the research. However, the subsequent study, outlined in Section II.3, Section II.4, Section II.5, and Section II.6, which pertained to the capacity assessment of African UNESCO actors, utilized an approved questionnaire. As the author of this thesis conducted the study in the facility of the Department of Geography at Heidelberg University of Education, Germany, which hosts the UNESCO Chair on Observation and Education of World Heritage & Biosphere Reserve, the questionnaire underwent approval there. Additionally, an approved self-administered questionnaire for ethical review indicated no potential harm to respondents, and therefore, no formal voting process was necessary from the ethical committee of Heidelberg University of Education.

Throughout the studies within this thesis, strict adherence to established scientific practices was maintained, including principles such as informed consent to participate, consent to record interviews, anonymity of responses, data privacy, and participants' rights to withdraw from the study at any stage. These practices were per ethical guidelines outlined by reputable organizations such as the American Psychological Association APA (2016). Before their involvement, participants were fully informed about the purpose, significance, and implications of the study. To ensure confidentiality, personally identifiable information such as names was neither collected nor documented, and participants were instead assigned identification codes. Despite these measures, five individuals chose to voluntarily withdraw from the study without providing reasons or explanations.

Following the implementation of the research methods outlined above and described in Figure I.4–1, a multitude of insightful findings emerged. These findings are presented in the subsequent chapter.

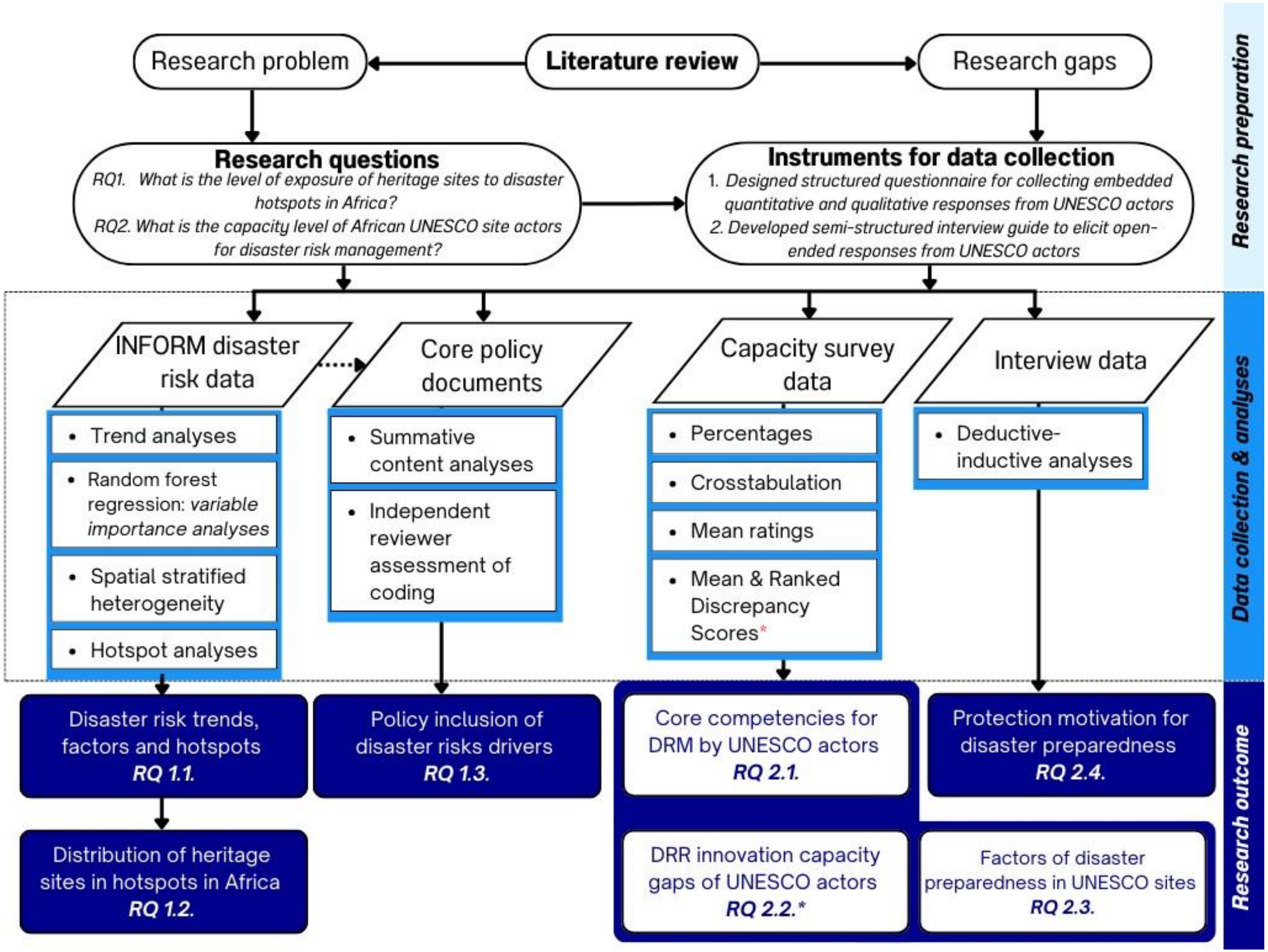

Figure I.4–1: Research design and process

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"We cannot stop natural disasters but we can arm ourselves with knowledge: so many lives wouldn't have to be lost if there was enough disaster preparedness." ~ Petra Nemcova

I.5. Scientific contributions

The primary findings addressing the research questions outlined in Section I.1.2. are presented below, along with their relevance and limitations. Detailed discussions of all results can be found in Part II of this thesis, which contains the accompanying publications. Key findings are hereunder highlighted in bold font in each subsection.

I.5.1. Research Question 1

The first research question (RQ 1) of this study warranted the investigation of the extent of exposure of UNESCO-designated heritage sites to disaster risk hotspots in Africa. The findings presented here draw from Chapters II.1 and II.2, corresponding to the studies of Eze and Siegmund (2024a) and (2024b). Overall, the answer to this research question offers fresh insights into the intricate nature of Africa's disaster risks, illustrates the extent to which UNESCO-designated natural and cultural sites are exposed to disaster hotspots, and shows the coverage of disaster risk drivers within core disaster risk management policies.

Research Question 1.1: Disaster risk trends, factors, and hotspots in Africa

Two objectives were pursued in this research question, namely, analysing the INFORM data for 2013 to 2023, to (i) unveil the patterns and trends of disaster risk in Africa, and (ii) identify the key drivers of disaster risk in Africa. Key contributions are presented below.

Throughout the period 2012 to 2022, Africa saw a modest rise in disaster risk in most regions. It is noteworthy that contrasting results were obtained between the smoothened trend line plots, which showed a slight increase, and the Mann-Kendall trend analysis, which indicated a non-significant declining trend in disaster risk across Africa. Conversely, both smoothened trend line plots and outcomes from the Mann-Kendall analysis emphasized increasing disaster risks in Eastern, Western, and Southern Africa. Countries like Cameroon, Chad, Ethiopia, Mali, Mozambique, Niger, South Sudan, Sudan, and the United Republic of

Tanzania consistently displayed rising disaster risk trends. Notably, infrastructural deficiencies showed a consistent decrease across all African regions, contrasting with the escalating lack of institutional coping capacity.

Vulnerability and lack of coping capacity factors are prominent disaster risk drivers. The results of random forest machine learning regression analyses indicate four distinct disaster risk drivers within both vulnerability and coping capacity categories, and three within the hazard category encompassing both natural and human-induced hazards. Within vulnerability, poverty (including development and deprivation), the prevalence of uprooted people, the health status of children under five, and food security have emerged as key factors influencing disaster risk in Africa over the past decade. Additionally, low-capacity levels in governance, physical infrastructure, access to healthcare, and communication facilities significantly contributed to disaster risk. Furthermore, natural drivers such as epidemics and physical exposure to floods, along with human-induced factors like projected conflict risk, play pivotal roles in shaping disaster dynamics across the region. Thus, an intricate interplay of the three components of disaster (i.e., hazards, vulnerability, and lack of coping capacity) exists in the African context.

Human-induced hazards, vulnerable groups, and lack of infrastructural coping capacity are the strongest risk factors. From the assessment of the six core factors of disaster risks in INFORM, vulnerable groups such as refugees, internally displaced persons, children under five, and others; human-induced hazards including current and projected violent conflicts, and lack of infrastructural coping capacity notably contribute to spatially stratified heterogeneity of disaster risk levels observed in the African context. Specifically, results of q statistics show that vulnerable groups significantly explain up to 100%, human-induced hazards up to 92%, and lack of infrastructural coping capacity up to 88% of disaster risks in different regions of Africa.

The interactions between human-induced hazards and the five other factors were the most robust. Risk factor interaction between human-induced hazards and lack of infrastructural coping capacity, institutional coping capacity, natural hazards, socioeconomic vulnerability, and vulnerable groups were consistently the most robust across various regions in Africa. Also, these were bi-enhanced interactions, signifying that their combined effect on disaster risks surpasses the mere sum of their (individual) influences.

Research Question 1.2: Distribution of heritage sites within disaster risk hotspots in Africa

Two objectives were pursued in this sub-research question based on the completed decadal analyses of the INFORM data for 2013 to 2023. Here, (i) disaster risk hotspots in Africa and presented, as well as (ii) a map of heritage sites located in these hotspots. The results of the second objective (ii) have not been presented elsewhere.

One-third of the 53 countries analysed are disaster risk hotspots. Results of the optimised hotspot analyses indicate that 19 countries were designated as hotspots. These countries, mostly sub-Saharan countries include Burundi, Cameroon, Central African Republic, Chad, Congo, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Kenya, Libya, Malawi, Niger, Nigeria, Sudan, Uganda, and United Republic of Tanzania. Furthermore, an emerging hotspot analysis unveils Eritrea as a new hotspot, depicting a recent notable increase in disaster risks. Also, seven countries, including Burundi, Chad, Djibouti, Niger, Rwanda, Somalia, and Uganda, demonstrated a continuous increase in disaster risks over the analyzed period and deemed consecutive hotspots. Additionally, distinct patterns were observed in certain countries: Central African Republic and Kenya showed escalating disaster risks as intensifying hotspots, while Ethiopia, South Sudan, and Sudan maintained consistently high disaster risk levels as persistent hotspots.

About 41% of UNESCO-designated heritage sites in Africa are within disaster hotspots. Results of the optimised hotspot analyses show that out of 268 heritage sites in Africa, 109 of them are in countries that are identified as hotspots with at least 90 % statistical confidence (Figure I.5–1). Further emerging hotspot trend analyses highlight that 47 of the African sites, representing around 17%, are distributed across different hotspot types, indicating elevated exposure and risk levels. For instance, Eritrea noted as a new hotspot, is home to one site. Conversely, countries like Ethiopia and Sudan, identified as persistent hotspots, host 16 and 6 sites respectively. Kenya, characterized as an intensifying hotspot, accommodates 13 sites facing escalating risks. Additionally, two consecutive hotspots, Niger, and Uganda, contain six and five sites respectively. **There is therefore a substantial presence of UNESCO-designated heritage sites in regions of high disaster risks across Africa, especially sub-Saharan Africa.**

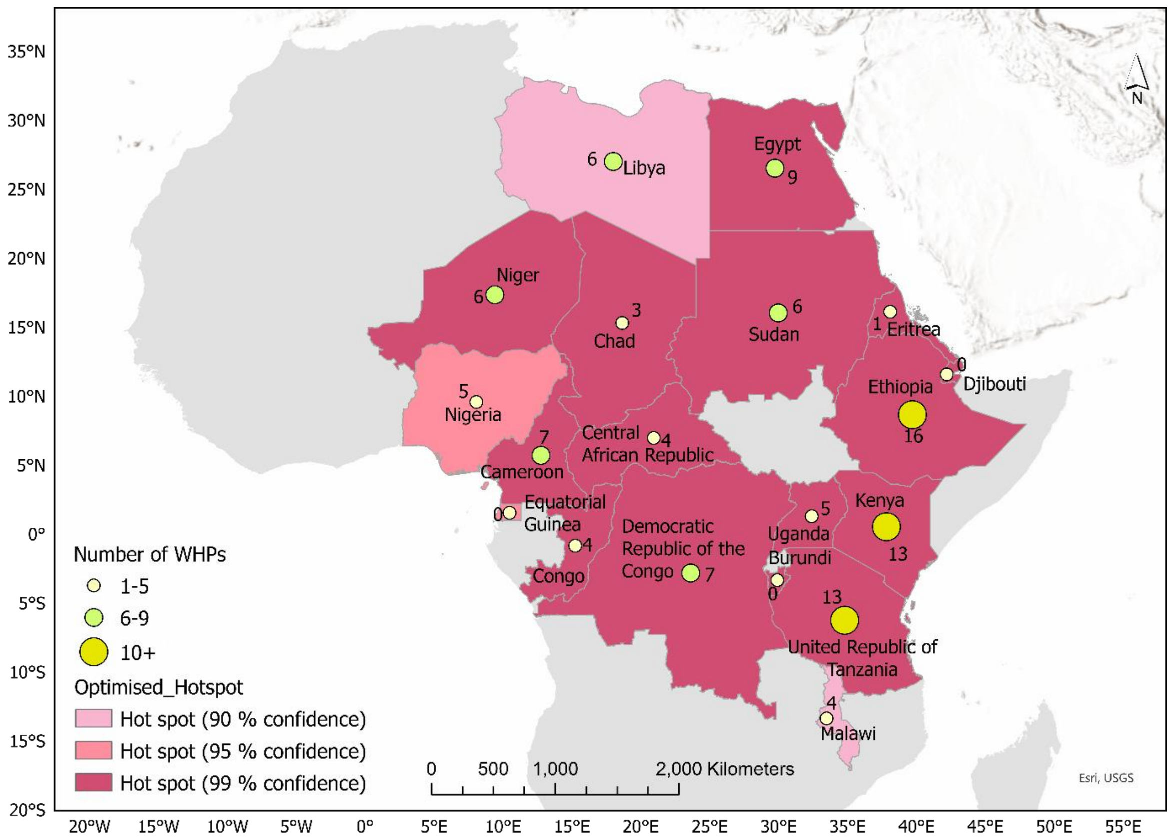

Figure I.5–1: Disaster hotspots in Africa and the number of UNESCO-designated properties

Research Question 1.3: Policy inclusion of disaster risk drivers in at-most-risk African countries

This research question was posed to assess how much policies incorporate disaster risk drivers in their development. Initially, the disaster risk drivers were identified using data from INFORM for 2022. Subsequently, content analyses were conducted on existing core policies from ten countries identified as having very high disaster risk indexes.

Violent conflicts were the only hazard drivers of Africa's disaster risks in 2022. The variable importance analyses revealed ten key disaster risk drivers, comprising projected conflict risk, current highly violent conflict intensity, development, and deprivation (i.e., poverty levels), vulnerable groups, uprooted people, governance, infrastructure, communication, physical exposure, and access to healthcare.

Vulnerability concepts dominate policies. Among the 25 policy documents analyzed from the at-most-risk African countries, a total of 3958 keywords relating to the top disaster risk drivers were identified. Classifying these keywords into the three disaster risk components of hazard, vulnerability, and lack of coping capacity, respectively yielded 4.27%, 64.96%, and 30.77% of the total keyword count in the policies. Therefore, the core policies of at-most-risk countries did not incorporate human hazard drivers identified in this study except countries like Somalia, South Sudan, and the Democratic Republic of Congo whose policies showed limited mentions of conflict-related concepts. Conversely, vulnerability-related concepts were more extensively covered in these documents, followed by indicators of insufficient coping capacity. Lastly, **countries with higher disaster risk indexes tended to incorporate a greater number of concepts related to disaster risk drivers within their policies.** In other words, as the overall disaster risk index increased for a given country, its policymakers addressed a broader range of disaster risk drivers within their policy frameworks.

I.5.2. Research Question 2

The second research question (RQ 2) of this study necessitates the comprehensive evaluation of different dimensions of capacity among African UNESCO site managers for disaster risk management. The findings presented here, especially for sub-questions RQ 2.1., RQ 2.2. and RQ 2.3., are exclusive to this thesis and have not been reported elsewhere. They are derived from a self-designed global survey, detailed in Section II.3, Section II.4, and Section II.5, corresponding to the respective studies. Eze and Siegmund (2024c); (2024d); (2024e). In addition, the last component in RQ 2.4. and Eze et al. (2024) is derived from the outcomes of interviews conducted with UNESCO actors of African heritage sites. Collectively, these findings offer data-driven insights into the capacity gaps that need to be addressed to enhance disaster risk management within African heritage sites.

Research Question 2.1: Next-generation core disaster risk management competencies held by UNESCO site actors

This research question investigated the levels of core disaster risk management competencies held by UNESCO site actors. This competency assessment study focused on three components of next-generation core disaster risk management competencies, assessing respondents as individuals, practitioners, and relationship-builders. **African respondents consistently scored higher than their counterparts from other regions of the world across all three tested components.** Thus, UNESCO actors from Africa demonstrate very high proficiency in disaster risk management competencies tested in this study. The ratings of these items are presented in Table II.4–5.

Table I.5–1: Mean ratings of listed disaster risk management next-generation core competencies

DRM next-generation core competency items	Mean	Std. Deviation
I possess critical thinking for problem identification and solutions	5.73	0.70
I demonstrate Professional ethics of respect, justice, integrity, and selfless service	6.27	0.59
I engage in continual learning and knowledge expansion	6.27	0.88
I consider all hazards, phases, stakeholders, and impacts relevant to disasters	5.40	1.40
I expect future disasters and develop disaster-resistant and disaster-resilient communities	5.27	1.33
I utilize sound risk management principles in assigning priorities and resources	4.40	1.55
I ensure unity of efforts among all community members to manage disaster risk	5.40	0.83
I create and sustain a team atmosphere to facilitate communication	6.40	0.83
I facilitate synchronous activities among all relevant stakeholders to achieve a common purpose	6.00	1.07
I use creative and innovative approaches to solving disaster challenges	5.27	1.16
I value a science and knowledge-based approach for continuous improvement	6.13	0.74
I consider, utilize, and value the growing body of disaster risk management literature for building disaster-resilient communities	5.67	1.18
I appreciate scientific processes and how their applications benefit humanity	6.20	1.15
The world is made of physical, built, and social systems, which interact in multifaceted ways, producing varying levels of risk and vulnerability	5.87	0.99
People and places are connected in a dynamic network of global relationships	6.07	0.70
I help others understand the relationship between social factors and disaster risk concentration	5.40	1.40
I use existing appropriate technologies in disaster risk management practice	4.67	1.50

I consider ethical, legal, and social implications when determining the appropriateness of a technology application for disaster risk management	4.80	1.78
I work in partnership with others and utilize a range of resources available within the system to establish an innovative solution to a pressing problem	5.73	1.28
I clearly communicate and explain hazard risks to a wide range of stakeholders	5.33	1.50
I understand and apply disaster risk management frameworks to identify and manage risks	5.13	1.51
I monitor, evaluate, and review risk management processes and outcomes	5.00	1.60
I involve the stakeholders to focus on the disaster risk exposure	5.33	1.35
I facilitate a community learning process through communication, dialogue, negotiation, and cooperation	5.67	1.40
I support community networks through the ongoing improvement of collective disaster risk reduction goals and interventions	5.33	1.50
I identify and analyse a hazard risk issue for action	5.13	1.30
I analyse access to the relational dynamics of, and the ramifications from those in positions of political power, policy, and legal parameters in connection to disaster risk issues	4.87	1.41
I bring people together across sectors to identify and address disaster risk issues at hand	5.33	1.29
I inspire a shared vision with community stakeholders and involve them to contribute to its achievement	5.53	1.30
I empower my staff to successfully pursue our organisation's vision	5.27	1.87
I resolve conflicts that emerge within or between the organization and the community it serves	6.13	0.99
Cluster mean	**5.52**	

n = 15

Additionally, the cluster analysis conducted to examine the relationship between expressed core disaster risk management competencies and site preparedness resulted in four clusters with different patterns (Table I.5–2).

Table I.5–2: Cluster membership and expressed disaster preparedness

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	None	Total
Prepared	4	0	2	0	0	6
Unprepared	2	0	2	2	0	6
None	2	0	0	1	11	14
Total	**8**	**0**	**4**	**3**	**11**	**26**

In Cluster 1, there were eight members with very high DRM core competencies. Among them, two reported their sites as unprepared for disasters, while four indicated their sites were prepared. Cluster 2 depicts very low DRM core competencies and includes no members. Cluster 3 comprised four members with high DRM core competencies, and an even split between those reporting prepared and unprepared sites. Lastly, Cluster 4 consisted of 2 members with moderate DRM core competencies, both reporting their sites were unprepared for disasters. Therefore, **higher competencies of UNESCO actors were generally associated with disaster preparedness on their sites.**

Research Question 2.2: Disaster risk reduction innovation competency gaps among UNESCO site actors

This research question focuses on the evaluation of preselected innovative disaster risk reduction products and approaches. Utilizing the Borich Needs Assessment Model and a recently developed Ranked Discrepancy Model, this needs assessment study identified training gaps in innovative disaster risk reduction. The key findings shed light on the levels of importance and capacity of African UNESCO actors in disaster risk reduction initiatives while highlighting prioritized training needs.

African UNESCO actors deemed **geographic information systems (GIS) and remote sensing as the most crucial disaster risk innovation technology, while they exhibited the highest competency and experience in the use of rainwater harvesting**. Three innovative disaster risk reduction technologies were rated as highly important, with seven others regarded as moderately important (Table I.5–3). However, among these ten items, UNESCO actors reported limited experience with four of the technologies and approaches, while they had no prior experience with the remaining ten (Table I.5–3). Moreover, like the results of the global survey, **African UNESCO actors identified Unmanned Aerial Vehicles (drones), GIS and remote sensing, and disaster prevention radio and telemetry systems as the most important**

products for which they require training. Table II.4–5 illustrates the results of both BNAM and RDM to show that respondents express a need for training across all listed technologies and approaches for disaster risk reduction, with particular emphasis on these top three identified items.

Table I.5–3: Mean ratings of importance and competence levels of innovative disaster risk reduction technologies and approaches

Tested DRRI	Importance (I)	Competence/ experience (C)	Gap (I–C)
GIS and remote sensing	3.27[v]	1.07[lc]	2.20
Unmanned aerial vehicles (drones)	3.07[v]	0.27[nc]	2.80
Social Networking Services (SNS)	3.07[v]	1.60[lc]	1.47
Disaster prevention radio and telemetry system	3.00[a]	0.93[nc]	2.07
Disaster risk insurance of persons and properties	2.80[a]	0.73[nc]	2.07
Rainwater harvesting	2.73[a]	1.73[lc]	1.00
Disaster resilient material	2.53[a]	0.80[nc]	1.73
Concrete and steel: building material and infrastructure	2.40[a]	1.07[lc]	1.33
Schools as cyclone shelter	2.27[a]	0.80[nc]	1.47
Doppler radar	2.13[a]	0.13[nc]	2.00
Earthquake early warning	1.93[l]	0.27[nc]	1.66
Electricity resistant survey	1.93[l]	0.93[nc]	1.00
Seismic micro zonation	1.73[l]	0.20[nc]	1.53
Seismic code	1.67[l]	0.27[nc]	1.40
Cluster mean	**2.47**	**0.77**	

[l] = of little importance; [a] = of average importance; [v] = very important
[nc] = no competence/experience; low competence/little experience
$n = 15$

Research Question 2.3: Factors of disaster preparedness in UNESCO sites
In response to this research question, various concepts were explored among UNESCO actors in African sites. These concepts include respondents' understanding of their site's outstanding values/features, perceived vulnerability, and disaster risk management (DRM) resources, collectively regarded as components of disaster awareness. In addition to the disaster awareness concept, the interconnections of risk perception, disaster experience, and exposure to disaster

preparedness were also assessed (Figure II.5–1). A combination of quantitative and qualitative data gave rise to insightful findings as follows.

Disaster exposure

African UNESCO sites are commonly exposed to wildfires, floods, violent conflicts, and droughts. Here, violent conflicts, therefore, broadened the spectrum of frequently occurring hazards, expanding the results of the global survey, which contained the other three hazards. In addition, the lower cluster mean for African respondents in Table I.5–4 (X = 2.43) depicts a lower exposure to frequent hazards than the global hazards exposure of X = 2.58 in Table II.5–2. Conversely, all respondents rated tsunamis and glacial lake outbursts as rarely occurring. Additionally, interview respondents mentioned windstorms and locust invasions as part of hazards. These were not originally included in the survey list.

Table I.5–4: Frequency of hazards

Hazards	Rarely occurring (%)	Frequently occurring (%)	Mention in interview responses (%) +	Mean
Forest Fire*	5.88	94.12	33.63	4.71
Land fire of Brush/bush/Pasture*	16.67	83.33	0.0	4.61
Flood*	22.22	77.78	32.31	4.22
Violent conflicts/riots/unrest/ protest*	25	75	2.86	3.75
Drought*	38.89	61.11	17.58	3.39
Dense Fog*	47.06	52.94		2.71
Extra-tropical storms e.g., cyclones, blizzards	52.94	47.06	7.91	2.76
Destructive wave actions	52.94	47.06	0.0	2.29
Extreme heatwave	55.56	44.44	0.0	2.83
Tropical storms e.g., hurricanes	64.71	35.29	0.0	2.41
Ground movement (Earthquake)	66.67	33.33	0.0	2.28
Severe winter conditions	70.59	29.41	0.0	1.71
Convective storms e.g., tornadoes	70.59	29.41	0.0	1.82

Landslide (dry)	76.47	23.53	5.05	1.71
Rockfall	77.78	22.22	0.0	1.94
Landslide (avalanche of snow, debris, or mudflow)	82.35	17.65	0.0	1.76
Extreme cold wave	82.35	17.65	0.0	1.41
Volcanic activity	94.12	5.88	0.0	0.94
Tsunami	100	0.0	0.0	0.67
Glacial Lake Outburst	100	0.0	0.0	0.65
Cluster mean				**2.43**

Quantitative $n = 28$; qualitative $n = 21$ | *Frequency ratings greater than 50%
$^{+}$Locust invasion = 0.44 %; windstorm = 0.22 %

Risk and vulnerability perception

Future disasters in African UNESCO sites will most likely threaten livelihoods, staff safety, and sites' integrity. UNESCO actors highly attribute these perceived disaster risks within their site to encroachment, development pressures, displacement, and accelerated deterioration of structures in addition to pollution, habitat loss, poaching, and reconstruction. However, risks related to hazards such as earthquakes, tsunamis, (extra) tropical storms like hurricanes, and tornadoes were very unlikely. Broadly, **African UNESCO actors express a higher level of risk perception than respondents from other parts of the world.** Moreover, the top factors of vulnerability by respondents in Figure I.5–2 indicate that **economic instability, environmental mismanagement, and climate change are key drivers of vulnerability to disasters in African heritage sites.**

Table I.5–5: Likely impact of future occurrence of disasters on or around UNESCO sites

Risk items	Unlikely (%)	Neutral (%)	Likely (%)	Mean
Injury, mortality, or displacement of staff that can reduce the capacity for security, monitoring and enforcement.	5.6	27.8	66.7	3.8
Loss of livelihood sources linked to the property.	11.1	22.2	66.7	3.8
Encroachment of people into the site	35.7	10.7	10.7	3.7

Pressure of development and illegal or uncontrolled development.	11.1	22.2	66.7	3.7
Damage or pressure caused by displaced peoples, particularly regarding camps of displaced peoples, their associated infrastructure and their waste and energy requirements.	16.7	16.7	66.7	3.5
Enhanced rate of deterioration of damaged wood or stone.	16.7	16.7	66.7	3.5
Pollution from waterborne debris and contaminated watercourses.	50	7.1	42.9	3.4
Damage to site-level office buildings and equipment	50	3.6	46.4	3.4
Damage to the property's outstanding universal value during emergency response activities.	16.7	38.9	44.4	3.3
Unique universal value and integrity are degraded through habitat loss and poaching.	27.8	16.7	55.6	3.3
Hazard-specific risks affect site-level staff	22.2	27.8	50	3.2
Water damage from firefighting.	60.7	14.3	25	2.9
Stealing of cultural artefacts on the site	50	16.7	33.3	2.7
Risk of the loss of authenticity or falsification through reconstruction.	38.9	27.8	33.3	2.7
Hurricanes and tornadoes can lead to storm surges, which can cause flooding.	77.8	11.1	11.1	1.7
Earthquakes on my site may cause a tsunami, fire, and landslides	35.7	53.6	10.7	1.4
Cluster mean				**3.13**

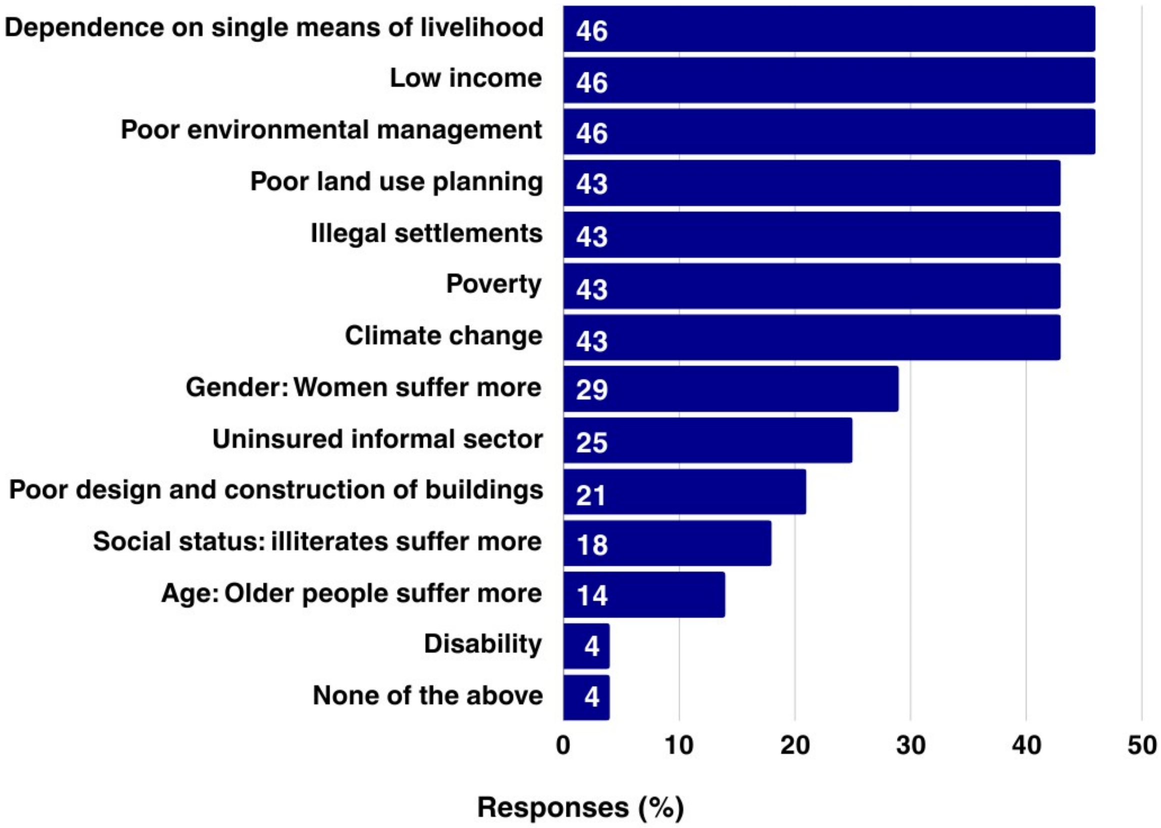

Figure I.5–2: Conditions that make UNESCO sites and their residents easily affected by the occurrence of a disaster | n =15

Available DRM resources

Smartphones are the most common DRM resource. Figure I.5–3 shows that smartphones emerged as the predominant DRM resource among African UNESCO actors, aligning with the global survey findings in Section II.5.3.3. Conversely, pagers were identified as the least available resource for disaster risk management.

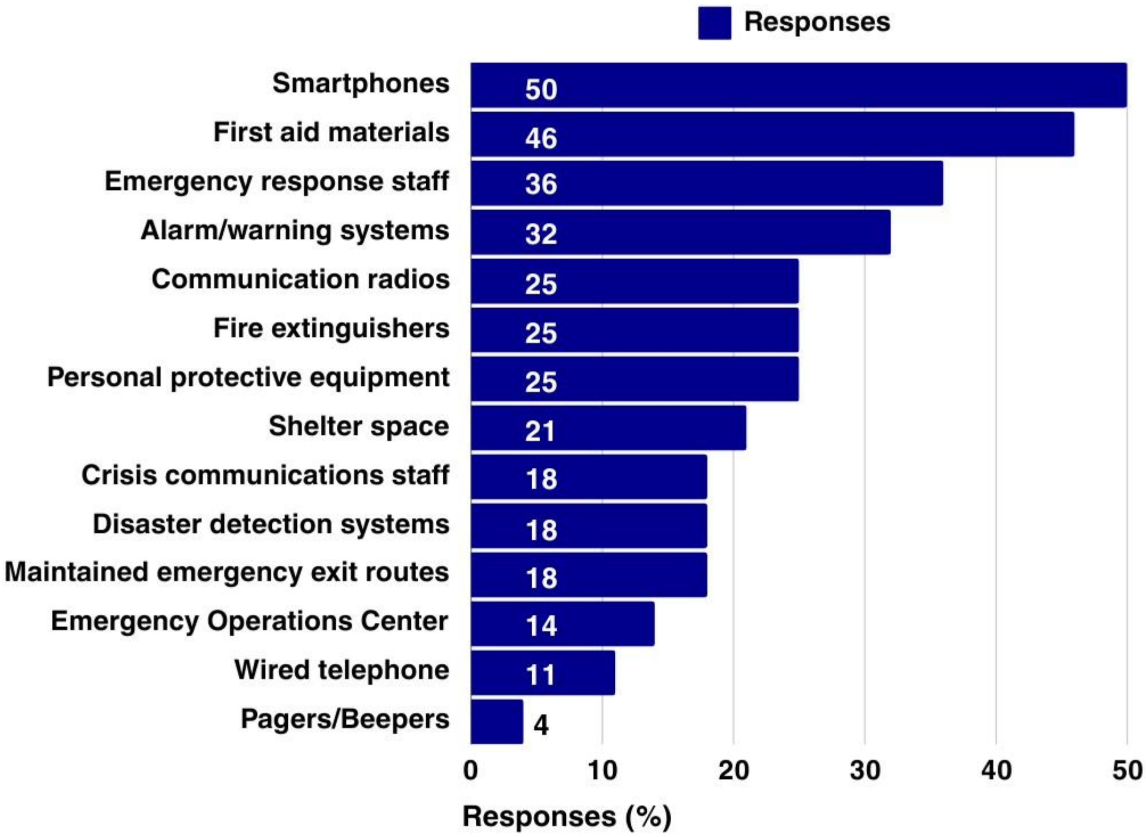

Figure I.5–3: Resources available for use in managing adverse conditions, risks, or disasters on UNESCO sites | n =15

Disaster experience

Most UNESCO actors have experienced frightening events and damages from past disasters but have not been directly harmed by previous disasters. Respondents conveyed varying degrees of direct (i.e., personal) and indirect (i.e., others') experiences with disasters and their consequences (Figure I.5–4a, d). More than half of the respondents reported suffering damages from previous disasters or experiencing frightening events that caused no harm. However, most respondents indicated that they had not personally experienced physical or emotional harm from disasters (Figure I.5–4b, c).

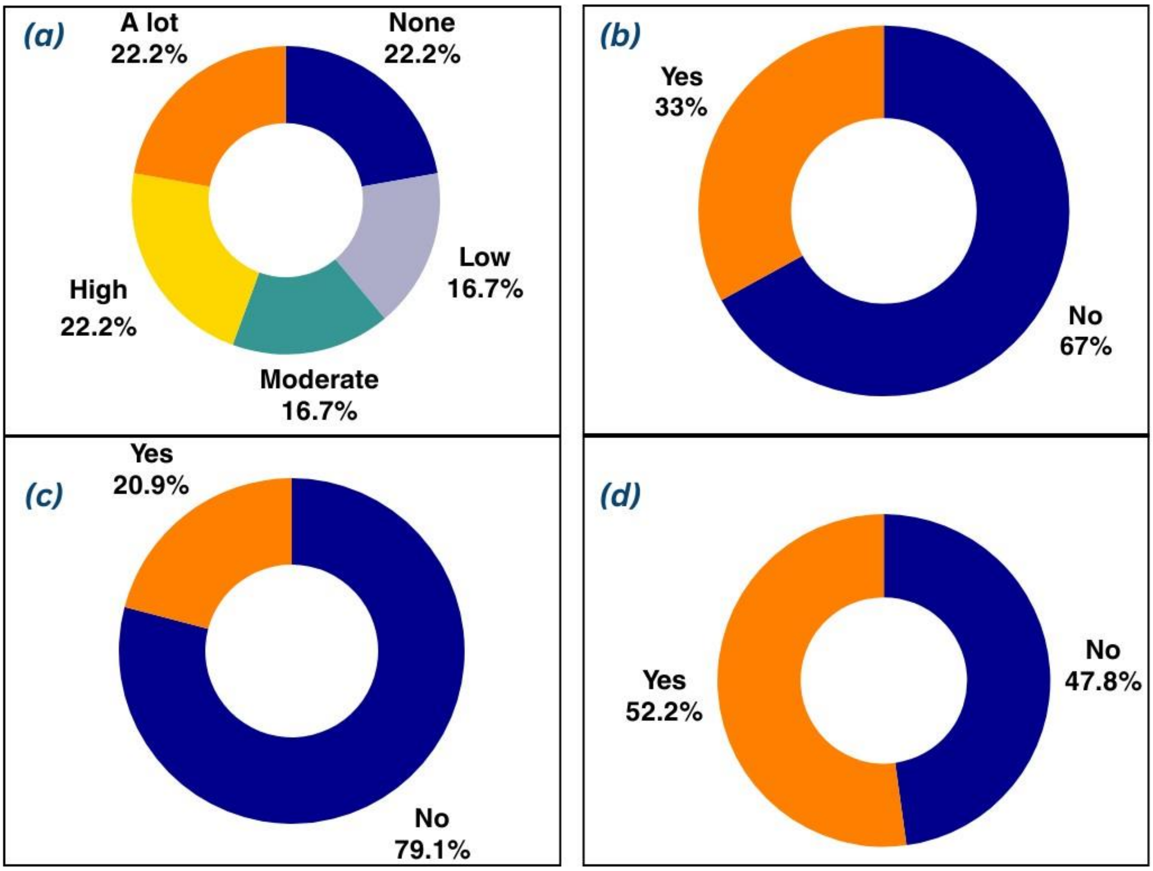

Figure I.5–4: Direct and indirect experiences with past disasters: (a) Damages from a past disaster (b) Physical harm from a past disaster (c) Emotional harm from a past disaster (d) Experience with frightening natural events | n =15

Disaster awareness

African UNESCO actors possess high awareness levels regarding relevant information related to their sites and constituents. Overall, their cluster mean awareness score in Table I.5–6 (X = 4.09) is higher than the global average of X = 3.73 in Table II.5–4. Thus, Table I.5–6 reveals that all respondents exhibit a high awareness of the essential attributes necessary for the inscription of properties on the UNESCO list. Moreover, the mean ratings indicate that awareness of existing site communities is the most highly rated item, suggesting community engagement and involvement in site management. Conversely, hazard-specific needs assessment receives the lowest rating, suggesting a potential area for improvement in understanding the specific requirements and challenges faced by the communities and sites in the face of hazards.

Table I.5–6: Level of awareness of items essential for disaster risk assessment

Items	Low (%)	High (%)	Mean
Existing community around the site	15.4	84.6	4.75
The attributes that carry the outstanding universal value and justify the criteria for inscription of the property on the UNESCO cultural/biosphere Heritage List	0.0	100	4.67
Geographical information on the location of the property, its boundaries, its buffer zone, its immediate surroundings, access, topography, and others	15.4	84.6	4.5
Existing relevant institutions within the site	16.7	83.3	4.5
Condition of roads for potential evacuation during a disaster	16.7	83.3	4.42
A list of factors and processes that will lead to damage or deterioration in the event of disaster occurrence	16.7	83.3	4.25
Physical planning (land use, transport and infrastructure) of the area in which the site is located	23.1	76.9	4.17
Complete and easily accessible directory of agencies that will act during disasters	23.1	76.9	4.17
Hydrological information on the water table, surface water such as rivers and others	16.7	83.3	4.08
Thematic maps of the area or region in which the property is located, such as a hazard vulnerability map	33.3	66.7	3.83
Local and traditional knowledge systems relevant to disaster risk reduction	33.3	66.7	3.83
Meteorological information on the nature of the climate	25.0	75.0	3.75
Inventories and the status of existing management systems and disaster preparedness equipment and facilities in the property, such as for shelter, evacuation, and rescue	25.0	75.0	3.75

Geological information on the nature of the soil and fault lines (if any)	25.0	75.0	3.67
Information on the history of different disasters affecting the area or the property itself	25.0	75.0	3.67
Evaluation of hazard-specific equipment and needs e.g., the different needs for floods, fires, landslides, pollution events and disease epidemics	46.2	53.8	3.5
Cluster mean			**4.09**

n = 15

Disaster preparedness

Concerted efforts are in place depicting disaster preparedness on African heritage sites, with considerable scope for improvement. Like the results of the global survey, top preparedness measures include stakeholder coordination and capacity building on the use of emergency equipment (Table I.5–7). These demonstrate proactive measures for disaster preparedness. However, evacuation plans and communication, installation and simulation drills for emergency equipment, which are more prevalent among respondents of other continents (Table II.5–5), represent critical areas requiring focus to enhance disaster preparedness in Africa.

Table I.5–7: Emergency provisions in place on sites

Items	No (%)	Yes (%)
Coordination between the site staff and security	33.33	66.7
Training and capacity-building on the use of emergency equipment such as fire extinguishers	33.33	66.7
A comprehensive strategy based on the main risks, the location of the property, and available resources and expertise is formulated	41.67	58.3
Organizing awareness-raising activities such as seminars and exhibitions	41.67	58.3
Maps of the property showing specific features such as utility mains, fire exits, fire extinguishers, and others	50.0	50.0
A well-developed plan and procedures for evacuating people is available	58.33	41.7
General emergency equipment is installed	58.33	41.7
Communication of the emergency plan and procedures to visitors, staff and local residents by	58.33	41.7

easily readable handbooks, manuals, drawings, and signage		
Alarm systems, special security cordons	66.67	33.3
Regular emergency simulation drills in cooperation with external agencies such as fire services	75.0	25.0

n = 15

African UNESCO actors demonstrate preparedness for the most common hazards, except for violent conflicts. Consistent with the global survey findings, their preparedness is highest for the hazards that occur most frequently (Table I.5–8). However, there is a notable absence of preparation for human-induced hazards at both the African and global levels.

Table I.5–8: Hazards for which UNESCO sites are prepared

Hazards	Responses (%)
Forest Fire	25.0
Flood	21.4
Land fire of Brush/bush/Pasture	17.9
Drought	17.9
Extreme heat wave	10.7
Tropical storms e.g., hurricanes	10.7
Dense Fog	7.1
Extra-tropical storms e.g., cyclones, blizzards	7.1
Destructive wave actions	7.1
Ground movement (Earthquake)	3.6
Severe winter conditions	3.6
Rockfall	3.6
Landslide (avalanche of snow, debris, or mudflow)	3.6
Landslide (dry)	3.6
Convective storms e.g., tornadoes	3.6
Volcanic activity	3.6
Extreme cold wave	0.0
Tsunami	0.0
Glacial Lake Outburst	0.0
Violent conflicts/wars/riots/unrest/protest	0.0
None of the above	3.6

n = 15

Factors of disaster preparedness in African sites

There is an even distribution of respondents based on their perceptions of disaster preparedness at their respective sites (Table I.5–9). **Hazard exposure, risk perception, resource availability, disaster experiences, and site awareness are associated with greater disaster preparedness on African heritage sites.** UNESCO actors with higher levels of hazard exposure, risk perception, available skills and resources, disaster experiences, and site awareness demonstrate greater disaster preparedness on their sites. However, it is concerning that a significant proportion of respondents report low disaster preparedness levels despite having high risk perception and site awareness levels. The presented results are descriptive due to the limitations posed by the small sample size, making extensive statistical analyses unfeasible.

Table I.5–9: Crosstab results of tested variables on disaster preparedness

Variables	Levels	Low preparedness *n* *(%)*	High preparedness *n* *(%)*	Total *(n)*
Site type	World Heritage Site	2 (33.33)	3 (50.00)	5
	Biosphere Reserve	4 (66.67)	3 (50.00)	7
	Total	**6**	**6**	**12**
Hazard exposure level	Low	5 (83.33)	3 (50.00)	8
	High	1 (16.7)	3 (50.00)	4
	Total	**6**	**6**	**12**
Risk perception levels	Low	2 (33.33)	0 (0.0)	2
	High	4 (66.67)	6 (100.0)	10
	Total	**6**	**6**	**12**
Available Skills & resources	Low	6 (100.0)	1 (16.7)	7
	High	0 (0.0)	4 (66.67)	4
	Total	**6**	**5**	**11**
Disaster experience levels	Low	4 (66.67)	1 (16.7)	5
	High	2 (33.33)	5 (83.33)	7
	Total	**6**	**6**	**12**
Site awareness levels	Low	1 (16.7)	0 (0.0)	1
	High	5 (83.33)	6 (100.0)	11
	Total	**6**	**6**	**12**

Research question 2.4: Protection motivation for disaster preparedness and heritage conservation among African UNESCO actors

To address this sub-research question, the motivation dimension of capacity was assessed. Concise findings are presented below with further elaboration given in Section II.6, corresponding to Eze et al. (2024). Theoretically, this study advances the framework of the Protection Motivation Theory by identifying both supportive and non-supportive factors, thus contributing to scholarly discussions on disaster risk management and heritage conservation in Africa.

Risk perception and response efficacy are key protection motivation factors of actors within African heritage sites. There is a high level of risk perception and confidence in implemented risk reduction measures with low self-efficacy and response cost levels among African UNESCO actors. Most respondents exhibited high levels of perceived severity, vulnerability, and response efficacy. However, approximately half reported low self-efficacy alongside partial disaster preparedness, suggesting a connection between perceived capacity and readiness for disasters. Moreover, there is a noted inadequacy of human, material, and financial resources allocated to disaster risk management at African UNESCO-designated sites. **In addition to some elements of the protection motivation framework, heritage stewardship and individual commitment to sustainability and resilience serve as additional motivating factors for heritage protection** (Figure II.6–3).

I.5.3. Integration of quantitative and qualitative results

In line with the pragmatic research paradigm followed in this study, Table I.5–10 presents an integrated analysis of both quantitative and qualitative findings of the capacity assessment component of this study. Here, the table serves to highlight areas of convergence, where findings from the survey (quantitative) and interviews (qualitative) align, as well as areas of divergence, where discrepancies or differing perspectives emerge between the two data sources. This integrated approach provides a comprehensive view required of mixed-methods research.

Table I.5–10: Joint display of quantitative and qualitative results in this study

Key variables	Quantitative results	Qualitative results	Exemplar quotes from respondents	Analytical integration
Disaster risk management competency	Very high (X=5.52)	Low self-efficacy	"There's need for specific or special training in terms of disaster risk management and all that. Well-organized trainings in terms of how they can manage disasters, how they can prepare for disasters, response, and post-disaster risk assessment and also activities that would help build resilience in the communities, issues of climate change. Yeah, and even detailed trainings about specific areas that are affected…we should have more officers that are able to do wildlife issues for the birds and also best agricultural practices, water management, environmental management, land forestry and all that. I think the numbers of people that have the required competence in this area, their numbers is also not enough, so we cannot cover the area well." (002H, Pos. 97–98) (Eze et al., 2024)	The qualitative data results diverge from the quantitative responses regarding disaster risk management competency. Specifically, while the survey responses indicate very high competency levels, the interview responses reveal low confidence in site managers' ability to deal with potential threats. Conversely, there is a convergence in the inadequate capacity levels for implementing innovative disaster risk reduction technologies and techniques. Both the survey and interview responses agree on low capacity levels in this area.
Capacity in innovative disaster risk reduction technologies	Very low (X=0.77)			

Disaster exposure	Most frequent hazards: • Wildfire • Floods • Violent conflicts • Droughts	Most frequent hazards: • Wildfire • Floods • Droughts	Yeah, so some of the hazards that we've experienced...flooding of the lakes...to an extent that offices were submerged, gates were submerged, roads were submerged, yeah, so staff houses were submerged...if the hydrology of the lake changes definitely the proliferation of the algae will also be affected. And so we've seen now cases where sometimes these lakes have no birds, okay, because the chemistry has changed, it has affected the availability of food and we don't know, we don't know now the cascading effect of that because normally in ecology we say when one species is affected it affects another, that other affects another one, so it has a ripple effect or a cascading effect in the long term...But we also have cases of landslides and rockfall…Then of course we also have cases of wildfires...killing some species and all that, and therefore of course then also affecting the ecosystem services, either in the short term, but we never know,	There is a significant convergence between the quantitative and qualitative findings regarding the most frequent natural and human-induced disasters affecting heritage sites in Africa. Both approaches identify similar hazards, and they appear in the same order of frequency.

			perhaps also in the long term. (004U, Pos. 55-59)	
Risk perception	High (X=3.13)	High	"...Humidity brings deterioration to buildings. It brings damage, either through infiltration or capillary rise...When there is...rainfall, most of those houses built with mud and stone slabs become wet. Their floors become wet. And now, it will melt most of the structures. And for drought, you know...when droughts come in, most of the crops will not yield any produce." (001H, Pos. 156–158)	The results of both quantitative and qualitative data converge in showcasing a high level of risk perception among respondents. Both the survey and interview responses highlight the potential losses of structures and the impacts of future disasters on the sites, affecting both residents and the environment.
Vulnerability perception	Reported vulnerability factors: • Dependence on a single source of livelihood • Poor environmental management and planning	Emerged themes: • Poverty • Climate change • Poor land management practices • Gender and age of residents	"as the sites become vulnerable, people also become vulnerable, because people are living within these areas...in terms of gender, I think when these things happen, you find that women and girls, and even youth, are more vulnerable... When it comes to age, the old, the aged people, and the young ones are also more vulnerable. And this is now where sometimes when you're dealing with some of these disasters, we start asking ourselves, do we have data that can	From the survey and interview responses, there is partial convergence on key themes such as poverty, climate change, and poor environmental management. The survey indicates that dependence on a single source of livelihood is perceived as the highest vulnerability factor, while interviews frequently cite poverty and climate change as

	• Illegal settlement • Poverty • Climate change		really demonstrate that women and girls are more affected? Do we have data to show that maybe the aged and the very young ones are more affected? Do we have sex or gender desegregated data? That's another issue, and that's another gap in our case. So that's why I'm thinking, besides just mapping, we also want to start looking at how can we be able to come up with, you know, desegregated data." (004U, Pos. 86-90)	the primary vulnerability factors. Other factors vary distinctly between the survey and interview responses, further reflecting a partial divergence in results from both approaches.
Available resources for disaster risk management	Low levels of available resources. The most frequently available resources are: • Smartphones • First aid materials	Low response costs are rife in terms of: • Inadequate financial resources • Infrastructure limitations • Shortage of human resources	"I think the site is relatively unprepared for disaster management. This is related to financial needs, this is related to the need for capacity enhancement, that is, people who know themselves and who bring their know-how to the management team. This requires the mobilisation of a certain number of resources to make it available to our team, people who will train us to manage a certain type of disaster." (008H, Pos. 54)	Results of the quantitative and qualitative data collected in this study converge regarding the level of available resources for disaster risk management. there are low levels of financial, infrastructural and human resources available for managing disasters in heritage sites within Africa.
Disaster preparedness	Partially prepared	Partially prepared	"For this year, we know that we are going to have a drought, but	There is complete convergence in the disaster preparedness

	preparedness now is the problem. In the case of floods, people might know that we will have a flood, but they may not know exactly the extent and whether they are going to be personally affected by that flood. So, the forecast is there, but it's a bit more general...In terms of preparedness, yes, a lot of effort has been there, but sometimes the magnitude of the disaster exceeds what the measures of preparedness that have been put in place.” (016U, Pos. 100-101)	levels indicated in both the survey and interview responses. Responding UNESCO actors consistently agree that their heritage sites are only partially prepared for disasters.

Note: The unique code of respondents and the position (i.e., Pos) of the quoted text within the interview transcript as processed in MAXQDA are placed beside each quotation to provide precise referencing to the interview responses.

I.5.4. Summary of thesis' contributions

This thesis, through its rigorous methods and extensive analytical procedures, makes significant empirical, theoretical, and practical contributions to disaster science (Figure I.5–5). In addressing its two key research questions and achieving its aim and objectives, the thesis provides several notable insights.

Empirically, it sheds new light on the exposure of heritage sites in Africa to disasters, characterizes disaster risks and policy gaps in the region, and identifies capacities and capacity gaps among UNESCO actors at these sites, as well as factors influencing disaster preparedness. Theoretically, the study validates and extends the components of the protection motivation theory as adapted to this research context. Practically, the thesis offers valuable recommendations for advancing disaster management research, informing policy development, and improving practical applications in the field.

Aim	***to understand disaster risks and the capacity gaps required for their management within UNESCO-designated heritage sites in Africa***	
Research Questions	**1. What is the level of exposure of heritage sites to disaster hotspots in Africa?**	**2. What is the capacity level of African UNESCO site actors for disaster risk management?**
Contributions	**Empirical contributions:** 1. Nearly half (41%) of UNESCO-designated heritage sites in Africa are located in disaster hotspots. 2. Disaster risk factors in Africa are social and interconnected, with violent conflicts being the most influential. 3. Policy gaps exist in the at-most-risk African countries, as they inadequately incorporate hazard drivers of disaster risk.	**Empirical contributions:** 1. DRM core competency levels are high, covering individual, practitioner, and relationship-building components. 2. Experiences with implementing innovative approaches and technologies for disaster risk reduction are very low. 3. Heritage sites at-most-risk of disasters are largely unprepared. 4. Prior disaster experiences influence preparedness. **Theoretical contributions:** 1. Data-driven extension of the protection motivation theory with emerging concepts of ‘heritage stewardship’ and ‘sustainability commitment’.

Figure I.5–5: Summary of empirical and theoretical contributions of this thesis

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"Sometimes it takes a natural disaster to reveal a social disaster." ~ Jim Wallis

I.6. Synopsis and conclusions

This thesis explores the disaster risk exposure of UNESCO-designated heritage sites and the capacity for disaster risk management among relevant actors within these sites in Africa. The findings obtained provide essential insights required to bridge capacity gaps for improving disaster preparedness in these sites, particularly in sub-Saharan Africa. To provide a comprehensive understanding, two core aspects were considered: (i) identifying the exposure of African UNESCO-designated sites to disaster risk hotspots, and (ii) exploring diverse dimensions of the capacity levels of African UNESCO site managers for disaster risk management. The following paragraphs synthesize the connection between these aspects and present the conclusions drawn accordingly.

I.6.1. Results synthesis

Exposure of African UNESCO-designated heritage sites to disaster risks
Africa faces significant vulnerability to disasters, with profound implications for poverty and the preservation of our natural and cultural heritage. This thesis provides a comprehensive assessment of disaster risks in Africa, shedding light on the perilous exposure of our shared heritage to irreversible destruction if left unaddressed.

Analysis within RQ 1.1. with details in Section II.1 and Eze and Siegmund (2024a) spanning the years 2012 to 2022 reveal that three out of five regions experienced escalating risks, primarily driven by factors such as violent conflicts, population displacement, poverty, and deficiencies in institutional disaster risk reduction measures. Of particular concern are the interactions between these risk factors, notably with violent conflicts playing a prominent role. Unfortunately, as shown in the findings of RQ 1.2. and extensively presented in Section II.2 and Eze and Siegmund (2024b) policies in at-most-risk countries often fail to adequately address this critical risk factor. Ultimately, the research highlights that a significant portion of heritage sites in Africa (i.e., four out of ten) are situated within disaster risk hotspots.

The findings of this study unveil the profound humanitarian and environmental risks posed by disasters in Africa. While a previous report by

Mizutori and Guha-Sapir (2020) highlighted the increasing frequency and severity of global disaster events, another regional assessment by Aliyu (2015) has demonstrated the rising dimensions of disaster risks, including hazards and vulnerability. This study's contribution, therefore, goes beyond nebulous postulations to offer deeper insights into specific risk components within the hazards, vulnerability, and capacity dimensions, providing a more comprehensive understanding of the disaster risk landscape in Africa. Moreover, human-induced hazards emerge as the most significant driver of disaster risks in Africa.

The interaction effects of human-induced hazards, particularly violent conflicts, with other categories of disaster risk factors, such as natural hazards, socio-economic vulnerability, vulnerable groups, and insufficient institutional and infrastructural coping capacity, were found to be particularly significant in some regions of Africa. In fact, these interactions reached 100% for certain areas, indicating a very strong interconnection among different risk factors. Violent conflicts have been aptly characterized by Anderson et al. (2021) as a significant factor contributing to disaster risks and a barrier to sustainable development. This is due to the potential for increased food insecurity, distressing displacement of people, and profound impacts on vulnerable groups (Anderson et al., 2021). Unfortunately, violent conflicts are inadequately addressed in the formulation of disaster-related policies in the at-most-risk African countries as depicted in RQ 1.2 and Eze and Siegmund (2024ab). This underscores the urgent need for comprehensive, inclusive, and adaptable policy frameworks to address this critical gap (Eze & Siegmund, 2024ab).

Hence, another vital contribution of this study is the characterisation of disaster risk drivers. Across all three risk components–hazards, vulnerability, and coping capacity–disaster risk drivers in Africa are predominantly social factors. This is close to earlier conceptualizations by Bailey (2022), who framed disasters as resulting from natural hazards interacting with weak social systems, a notion echoed by Ginige (2011), who suggested that social factors are more controllable compared to natural hazards. However, these studies fail to account for human-induced hazards such as violent conflicts. Responses from interviews conducted with UNESCO actors for other portions of this thesis corroborate the notion that Africa's disaster risks are primarily rooted in social factors. The accounts provided by UNESCO actors reveal that hazards within heritage sites in Africa are predominantly anthropogenic, with few instances of nature-induced disasters. Thus, as deduced from the works of Samaraweera (2024), and Imperiale and Vanclay (2021) social risks could significantly undermine the resilience and well-being of these heritage sites and their occupants when confronted with hazards. Sadly, with low resilience levels hazards would always translate to disasters and their attendant impacts (Eze & Siegmund, 2024da).

The broad disaster risk assessment conducted within this study not only showcased trends, drivers, and patterns of risks and hotspots but also revealed the high degree of exposure of UNESCO-designated heritage sites to disaster risk hotspots. Since these findings are based on long-term data, they hold utility. In agreement with Kelman et al. (2015), these results could inform the development of intervention strategies aimed at reducing vulnerability while fostering resilience. Notably, resilience building and vulnerability reduction are not always mutually exclusive. For instance, while addressing both the remote and immediate causes of violent conflicts can mitigate displacement, enhancing institutional capacity for disaster risk reduction may not directly alleviate poverty. Therefore, to effectively mitigate the impacts of hazards and disaster risks on human populations, the environment, and our natural and cultural heritage, intentional efforts must be made to integrate both resilience-building and vulnerability reduction measures, as emphasized by Imperiale and Vanclay (2021).

Furthermore, this study corroborates the findings of Hølleland et al. (2019). Their research identified war and civil unrest as the primary factors behind the inclusion of 48% of African heritage sites on UNESCO's World Heritage in Danger list. By reaffirming the role of violent conflicts as substantial drivers of disaster risks and threats to heritage sites, our findings align with and support those of Hølleland et al. (2019). According to the guidelines of UNESCO (2021), heritage sites are added to the World Heritage in Danger list if either ascertained or potential dangers from natural or human causes are established. Ascertained dangers encompass various forms of substantial deterioration of materials, structures, or the natural environment, as well as significant loss of historical authenticity or cultural significance. Additionally, threats from human activities like settlement expansion, poaching, or extractive practices endangering heritage sites' integrity are regarded as ascertained dangers. On the other hand, potential danger factors include the outbreak or threat of armed conflict, risks posed by climatic, geological, or environmental factors, and the absence or inefficiency of conservation policies and management practices.

Thus, the findings of this thesis comprehensively cover all dimensions of disaster risk, as recommended by the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015). By providing a detailed understanding of disaster risk complexities in Africa and identifying critical assets at risk, such as natural and cultural heritage sites, this valuable knowledge can be utilized by relevant stakeholders for local-level disaster risk assessment, preparedness, response, as well as policy and practice development. Moreover, scarce resources can be efficiently allocated to countries with utmost needs.

Capacity of UNESCO actors in disaster risk management

This thesis builds upon the insights gained from assessing Africa's disaster risks in RQ 1. To examine different dimensions of capacity among UNESCO actors affiliated with African heritage sites. Results of RQ 2.1. show that while UNESCO actors possess high next-generation core competencies in disaster risk management, there exists a notable lack of proficiency in innovative approaches and technologies for disaster risk reduction, as highlighted in RQ 2.2. Furthermore, RQ 2.3. identifies various factors, including hazard exposure, risk perception, resource availability, disaster experiences, and site awareness, which are associated with greater disaster preparedness of African heritage sites. Additionally, findings from RQ 2.4. show that risk perception, response efficacy, heritage stewardship and a personal commitment to sustainability and resilience serve as motivating factors for disaster preparedness and heritage protection among UNESCO actors. Integration of all results shows that half of the African UNESCO actors interviewed, whose heritage sites lack disaster preparedness, are situated in countries classified as disaster risk hotspots. Hence, at-most-risk heritage sites in Africa are mostly unprepared for disasters.

Consequently, the findings from RQ 2, fully detailed in Eze and Siegmund (2024c), (2024d), (2024e) and Eze et al. (2024), respectively, represent pioneering efforts in assessing the disaster risk management capacity among UNESCO actors or other key stakeholders in Africa. These insights are, therefore, to pave the way for the development of tailored capacity-building initiatives aimed at enhancing heritage protection and disaster preparedness. It is noteworthy that African UNESCO actors scored very highly in the next-generation core competencies of disaster risk management developed by Feldmann-Jensen et al. (2019), which was tested in RQ 2.1. These competencies, which encompass various aspects related to individuals, practitioners, and relationship building, indicate a significant level of readiness to address disasters by these UNESCO actors within heritage sites in Africa. Therefore, despite the vulnerabilities to disasters, the self-efficacy of African UNESCO actors remains robust.

The findings from RQ 2.2. mark a significant advancement in identifying competency gaps concerning innovative disaster risk reduction technologies and approaches. In an era where high-precision technology-supported disaster risk management is increasingly crucial, addressing the current deficiency in capacity among African UNESCO actors in adopting and utilizing these tools is imperative. Swift action is needed to reverse this trend and enhance the readiness of actors to leverage innovative solutions for disaster risk reduction. The relevance of these innovative approaches to reducing disaster risks, especially within the context of the Sendai Framework is sufficiently documented in Shaw et al. (2018); Izumi et al. (2019); Fontes de Meira and Bello (2020); and Shaw and Kanbara (2022).

Hence, the findings of this thesis provide essential inputs necessary for developing tailored professional development opportunities aimed at strengthening disaster preparedness and resilience among African UNESCO actors within their heritage sites. Given the robust competencies already demonstrated by these actors in disaster risk management, enhancing their proficiency in utilizing contemporary technological tools and innovative approaches will further empower them to advance disaster risk reduction efforts, thereby safeguarding our collective heritage from the imminent dangers posed by disaster risks. Moreover, within the contributions of RQ 2.3. the thesis identifies that UNESCO actors who exhibit higher levels of hazard exposure, risk perception, response resources, awareness of the site's value, and previous disaster experiences tend to be more prepared for disasters.

Consequently, alongside resource mobilization for increased disaster preparedness in these sites, the adoption of experiential learning and knowledge-sharing forums for actors becomes expedient. Recently, a study by Tasantab et al. (2023) discovered that integrating simulation-based experiential learning into disaster risk management education enhanced learners' abilities to apply knowledge and make critical decisions. In addition, experiential learning improved learners' practical experience, and capacity to work with diverse perspectives. Thus, including experiential learning within capacity-building programmes would simulate disaster experiences for individuals who have not encountered disasters, aiming to enhance disaster preparedness accordingly.

Additionally, based on the outcomes of RQ 2.4., capacity-building initiatives must prioritize stimulating heritage stewardship and fostering personal commitment to sustainability and resilience among African UNESCO actors. Heritage stewardship, according to Welchman (2016), refers to the practice of protecting, preserving and safeguarding the integrity of cultural and natural heritage for their significance in perpetuating the identity and values of a specific community across generations. Moreover, personal environmental commitment, as defined by Stern (2000) and Raymond et al. (2011), encompasses an individual's perceived sense of obligation toward the environment. This commitment significantly influences pro-environmental behaviors, as highlighted by Yu et al. (2019), who suggest that individuals are more motivated to engage in environmentally friendly actions when they align with their personal priorities, including their level of environmental commitment. Therefore, implementing capacity-building approaches aimed at fostering personal commitment to sustainability among UNESCO actors will likely enhance their motivation to participate in disaster preparedness efforts and heritage conservation initiatives.

By nurturing the factors of motivation for heritage protection and enhanced disaster preparedness in this study, relevant actors could proactively safeguard our invaluable heritage. Therefore, implementing targeted interventions, policies, and programs based on the findings of this thesis can bridge resilience and resource gaps, ensuring effective response and preservation efforts. Ultimately, enhanced resilience and disaster preparedness mitigate risks and safeguard the sustainable future of Africa's cultural and natural heritage for generations to come.

I.6.2. Conclusions

This thesis embodies studies that sought to deepen the understanding of disaster risks in Africa and their management within the context of heritage sites through comprehensive disaster risk and capacity assessments. The analytical efforts undertaken to address the two overarching objectives and research questions led to the following key conclusions:

African disaster risk drivers are social and interconnected. Within all components of disaster risks, encompassing hazards, vulnerability, and coping capacity, social factors play a central role in Africa. While studies such as Samaraweera (2024) and Imperiale and Vanclay (2021) associate vulnerability and coping capacity with social elements, this study reveals an unexpected finding: violent conflicts, a human hazard component, emerge as a significant anthropogenic driver of disaster risks in Africa. This thesis demonstrates that violent conflicts interact extensively with other factors, exacerbating vulnerabilities and deficiencies in coping capacity. Remarkably, despite their pronounced interaction effects in shaping disaster risk landscapes in Africa, they are not considerably reflected in the development of core policies of at-most-risk countries.

Nearly half of African heritage sites face imminent threats. Through a meticulous examination of a decade's worth of disaster risk data, it becomes evident that 41 % of these sites are located within hotspots in Africa, demanding urgent attention. The insights from Hølleland et al. (2019), who attribute nearly half of African heritage in danger to the ravages of wars and civil unrest, are corroborated by this study. Thus, there is a pressing need to reiterate the imperative of addressing the social dimensions of disasters in Africa as they pose a substantial risk to the long-term conservation of heritage sites. Implementing both prospective and corrective disaster risk management measures is essential to prevent new risks and reduce existing risks threatening the loss of heritage already located in disaster risk hotspots.

Several conceptual contributions emanate from addressing the first objective of this study. First, the complex interaction between human-induced hazards, particularly violent conflicts, and other social factors underlying disasters is unveiled. Secondly, the study diverges from the conventional narrative in the African disaster literature dominated by natural hazards, showcasing the importance of incorporating the human-induced hazard drivers of disaster risks. Lastly, a policy blind spot in at-most-risk countries is highlighted, where the most influential disaster risk driver, violent conflict, remains inadequately addressed.

Therefore, to reduce disaster risks, build resilience, and conserve heritage sites in Africa, the study urges a re-evaluation of disaster risk management policies and strategies to comprehensively address the social dimensions of disasters, considering their intricate interconnections. By doing so, potential threats to heritage sites can be effectively reduced, ensuring the preservation of Africa's invaluable cultural and natural heritage for future generations.

Vulnerability does not equate to a lack of capacity. The decadal analysis of disaster risks using INFORM data reveals that while the vulnerability trend increased, deficiencies in infrastructural coping capacity simultaneously plummeted. This suggests an overall enhancement in access to critical services such as electricity, internet connectivity, mobile networks, roads, clean water, sanitation facilities, and healthcare across Africa from 2012 to 2022. Additionally, insights gathered from surveys and interviews of UNESCO actors show that despite the persistently high perception of vulnerability, there is also a high level of competency in disaster risk management among these stakeholders. Studies by Imperiale and Vanclay (2016, 2021) demonstrate that communities with high levels of vulnerability could also possess resources that increase their resilience in times of crises and disasters. Consequently, an integrated and contextualized approach to vulnerability reduction and capacity building emerges as important for effective disaster risk management.

Capacity and resource gaps require urgent attention. There is a clear deficiency among UNESCO actors in utilizing essential geospatial technologies such as unmanned aerial vehicles (drones), geographic information systems (GIS), and remote sensing for effective disaster risk management. Furthermore, a lack of experience indicates a scarcity of both hardware and software components of these critical resources. In addition, emergency response resources are severely lacking. This combined inadequacy in capacity and resources across African heritage sites suggests challenges in predicting hazards and communicating early warnings for enhanced preparedness. Moreover, in the event of a hazard, the absence of resources will exacerbate the resulting losses. Therefore, an urgent intervention from relevant stakeholders is needed to address these gaps which collectively jeopardize the capacity to implement all the phases within the disaster management cycle (i.e., mitigation, preparedness, response, and recovery). As Kuglitsch et al. (2022), notes that the world increasingly adopts artificial intelligence for hazard mapping, monitoring, and timely communication, Africa must be supported to keep pace with these advancements. Such support aligns with the principles outlined in the Sendai Framework for Disaster Risk Reduction, particularly in facilitating knowledge sharing and technological transfer from developed to developing countries.

Therefore, the capacity assessment component of this study offers significant contributions. First, an initial overview of the gaps in resources, competencies, and motivation for heritage conservation and disaster risk reduction within African heritage sites is provided. Secondly, prioritized training needs for adopting innovative disaster risk reduction technologies and approaches are herein identified. Consequently, as a needs assessment, this study lays the groundwork for enabling the judicious deployment of limited financial resources to address urgent and critical resource and tailored professional needs, thereby enhancing resilience in African heritage sites. Moreover, other findings linking disaster experience to preparedness as well as personal elements such as heritage stewardship and personal commitment to sustainability further provide important insights to shape the approaches to capacity development for UNESCO actors and improve their motivation for heritage conservation.

In conclusion, this study offers both conceptual and theoretical contributions. Conceptually, a novel perspective is provided on the social factors driving disasters in Africa, enriching the understanding of disaster risks, while shedding light on critical gaps in disaster risk management policies, resources, and capacities. Theoretically, the study extends the Person-Relative-to-Event Model and Protection Motivation Theory by incorporating data-driven components derived from surveys and interviews with UNESCO actors. Incorporating the insights from this research into holistic disaster risk management approaches will help bridge policy and practice gaps, enhancing the resilience and sustainability of heritage sites in Africa.

I.6.3. Recommendations

Based on the findings from this study, several strategic recommendations are proposed to enhance disaster risk management for UNESCO-designated heritage sites in Africa. These recommendations aim to address identified policy and capacity gaps while leveraging existing competencies to improve the preparedness and resilience of heritage sites in Africa.

1. **Enhance resilience through disaster preparedness**

Since heritage sites in Africa are extensively exposed to disaster risk hotspots, reducing risks will require conducting frequent site-specific vulnerability and risk assessments, which are currently seldom implemented. From these assessments, the most vulnerable areas and their needs for priority attention will be uncovered. Subsequently, site-specific disaster preparedness and management plans could be further developed. Moreover, regular drills and simulation exercises should be conducted to test and refine preparedness plans.

2. **Address policy gaps to manage violent conflicts**

The omission of violent conflicts, the most influential risk factor, needs to be thoroughly addressed in core policies across Africa. Improved collaboration between academics, policymakers, and grassroots communities is essential to ensure comprehensive policies are developed following bottom-up approaches. Such policies must address all elements of risk, including violent conflicts, and should be regularly reviewed and updated based on new data and insights, such as those contained in this thesis.

3. Tailored professional development for capacity building

Ongoing, intensive, extensive, and hands-on training of UNESCO actors on innovative approaches and technologies for disaster risk reduction is urgently required to fill the capacity gaps identified in this study. Such training should be tailor-made to address preidentified needs. Based on this study, experiential learning methods and content that promote heritage stewardship and sustainability commitment are needed to improve preparedness and heritage protection motivation. Moreover, this study advocates for improved funding and resource provision for capacity development from governments and relevant funding institutions, while calling on heritage site managers and staff to utilize freely available online materials and resources for self-development.

4. Strengthen knowledge exchange networks for improved collaboration

Effective disaster risk management requires the collaboration of various stakeholders. Hence, the isolated efforts of researchers, policymakers, and heritage site actors should be integrated to enhance collaboration and knowledge sharing. Specifically, sharing information on past disaster events, their impacts, and response effectiveness can inform future preparedness strategies and disseminate best practices. Therefore, forums for regular deliberations among researchers, policymakers, and heritage site actors should be established. Such forums could serve as platforms for continuous knowledge exchange and collaboration among stakeholders for disaster risk reduction and sustainable heritage protection in Africa.

Implementing these recommendations will enhance the capacity of heritage sites in Africa to manage disaster risks. Improved capacity will significantly foster the resilience of these invaluable assets against future threats while preserving them for future generations.

I.6.4. Limitations

While the insights presented in this thesis are valuable, it is crucial to acknowledge certain limitations that impact the scope of the conclusions drawn. These constraints primarily relate to the study's design, methodology, spatial and temporal aspects, statistical analysis, and scope. These outlined limitations offer valuable insights that future research endeavours can leverage to enhance their design and achieve better outcomes.

Study design and methodology

The exploratory nature of this study inherently limits the possibility of representative sampling or validation. Additionally, the cross-sectional design of the policy analysis and competency surveys restricts the inclusion of a time dimension in the analysis of variables. The reliance on self-reported measures in surveys may introduce potential response bias, as participants may provide socially desirable responses, thus not accurately reflecting the actual levels of competencies, capacities, and capabilities measured. To mitigate the impact of cross-sectional limitations and potential bias, qualitative interview data were collected to complement the survey data.

The spatiotemporal decadal disaster risk assessment in this study relies on pre-existing INFORM datasets, which have their limitations, including potential incompleteness and concerns regarding data quality. For example, Marin-Ferrer et al. (2017) who describe the conceptual and methodological development processes of the INFORM data, have outlined methodological and data limitations, such as the use of proxies like malaria mortality rates for malaria prevalence, incomplete data, reliance on self-measured Hyogo self-assessment reports from countries, and the static nature of natural hazard data. Therefore, caution is advised when interpreting the results, considering these limitations and their potential impact on the study's conclusions.

In analyzing policies for their incorporation levels of disaster risk drivers, some documents underwent machine translation from French to English, potentially affecting the accuracy and understanding of the content, which could influence eventual interpretations. Furthermore, the summative quantitative content analysis employed for the policy analyses in this thesis is preliminary and exploratory, limited to the frequency count of disaster risk driver keywords within core policies of at-most-risk countries. However, this approach overlooks the broader context of the text (Hsieh & Shannon, 2005). To enhance the credibility of the technique in achieving this thesis' objective, an inter-rater reliability test was conducted, where an independent reviewer assessed six randomly selected policy documents using predefined keywords extracted for the study (Table II.2–2). This test yielded a substantial agreement of 90.73% with the obtained results.

Spatial and Temporal Limitations

The study's design was notably influenced by the scarcity of long-term data on disaster risk dynamics in Africa. While community-level disaster risk assessments were preferred, the absence of prior empirical assessments at lower scales constrained the study's scope. Additionally, the limited availability of local studies on disaster risk also hindered the validation of findings on smaller scales. Furthermore, the disaster risk assessment was conducted in the first quarter of 2023 and excluded subsequent disastrous events in 2023 and beyond, potentially altering the disaster risk dynamics of affected countries.

Statistical Limitations

While our smoothened trend plots provide valuable insights into disaster risk trends, the contrasting outcomes yielded by the Mann-Kendall MK results emphasize the complexity of trend analyses and necessitate a cautious interpretation of the study's findings. Additionally, both the Mean Weighted Discrepancy Score (MWDS) and Ranked Discrepancy Score (RDS) used in ranking training needs do not indicate the competency level of each respondent in adopting innovative disaster risk reduction technologies and approaches. Rather, these scores offer an overview of the entire sampled group of UNESCO actors.

Scope Restrictions

The focus on core policies from ten African countries limits the generalizability of the findings. While the policy analyses yielded insightful results on the policy coverage of disaster risk drivers, they may not fully represent the diversity of the African continent as only ten countries classified as very high risk were considered. Moreover, the study's reliance on non-probability sampling techniques and the low response rate further affects its generalizability. Despite multiple reminders, the response rate remained at 11%, hindering robust statistical analyses and compromising the representativeness of the findings. Additionally, the specific characteristics of the various UNESCO sites included in the study, along with the non-probability sampling techniques, may constrain the generalizability of the findings. Similarly, variations in disaster risk profiles and management practices across different regions and site types may not be fully captured due to the low and disproportionate responses within these groups.

I.6.5. Outlook

This thesis highlights the critical importance of identifying and understanding the drivers of disaster risks as a prerequisite for effective risk management. Consequently, there is a pressing need for additional research focusing on disaster risks in diverse local contexts across Africa, many of which remain largely unexplored. The broader topic of disaster risks, encompassing their management strategies and capacity gaps, represents a significant area of under-researched inquiry, presenting an opportunity for further exploration and advancement aligned with the priorities outlined in the Sendai Framework for Disaster Risk Reduction.

Therefore, it is recommended to undertake case studies, whose aims transcend the validation of the findings of the current study, to assess local-level disaster risk trends and factors, the efficacy of risk management interventions and their impacts on fluctuating levels of disaster risk over time. By investigating spatiotemporal factors, successful policies and practices that have contributed to the reduction of disaster risks in regions with declining risk levels, valuable insights can be gained. This knowledge can then be shared with countries of higher disaster risks for consideration and adaptation to their specific contexts, ultimately fostering improved disaster resilience and sustainability across the African continent.

Empirically, the research elicited perspectives from key stakeholders within UNESCO, including site managers, staff members, and representatives from UNESCO national commissions and the African unit at the UNESCO Headquarters in Paris, France. Future studies are required, delimited to African heritage sites already designated by UNESCO as part of the World Heritage in Danger list and those identified as being exposed to disaster risk hotspots within this study. Such investigations can explore the interplay of various factors driving disaster risks, adding depth to the broader findings of the current study.

Disaster science practitioners and stakeholders within UNESCO-designated heritage sites in Africa should prioritize continuous data collection and analysis using GIS and remote sensing technologies to obtain precise disaster risk information. Integrating scientific efforts with indigenous knowledge in policy development, capacity building, and targeted training programs for local actors, particularly UNESCO site managers, is essential for enhancing disaster preparedness. Additionally, conducting longitudinal studies and impact assessments will be crucial for tracking changes and refining interventions, ensuring the continuous and sustainable protection of Africa's cultural and natural heritage.

References (Part I)

Abdel Hamid, H., Wenlong, W., & Qiaomin, L. (2020). Environmental sensitivity of flash flood hazard using geospatial techniques. *Global Journal of Environmental Science and Management*, 6(1), 31-46.

Ahmadalipour, A., & Moradkhani, H. (2018). Multi-dimensional assessment of drought vulnerability in Africa: 1960–2100. *Science of the total environment*, 644, 520-535. https://doi.org/10.1016/j.scitotenv.2018.07.023

Aliyu, A. (2015). Management of disasters and complex emergencies in Africa: The challenges and constraints. *Annals of African Medicine*, 14(3), 123-131. https://doi.org/10.4103/1596-3519.149894

Anderson, W., Taylor, C., McDermid, S., Ilboudo-Nébié, E., Seager, R., Schlenker, W., Cottier, F., de Sherbinin, A., Mendeloff, D., & Markey, K. (2021). Violent conflict exacerbated drought-related food insecurity between 2009 and 2019 in sub-Saharan Africa. *Nature Food*, 2(8), 603-615. https://doi.org/10.1038/s43016-021-00327-4

APA. (2016). *Ethical principles of psychologists and code of conduct.* American Psychological Association. Retrieved October 27 from https://www.apa.org/ethics/code/ethics-code-2017.pdf

Armat, M. R., Assarroudi, A., & Rad, M. (2018). Inductive and deductive: Ambiguous labels in qualitative content analysis. *The Qualitative Report*, 23(1). https://doi.org/10.46743/2160-3715/2018.2872

Bailey, E. (2022). Disaster risk reduction and management: Recalling the need for paradigm shift in definition. *Journal of Geoscience and Environment Protection*, 10(6), 86-105. https://doi.org/10.4236/gep.2022.106006

Bari, M., & Dessus, S. (2022). *Adapting to Natural Disasters in Africa.* https://www.ifc.org/wps/wcm/connect/775d1c2f-a9f3-4b7d-b0d7-72738b42e3b8/Working-Paper-Adapting-to-Natural-Disasters-in-Africa.pdf?MOD=AJPERES&CVID=ohpHufW

Beccari, B. (2016). A Comparative Analysis of Disaster Risk, Vulnerability and Resilience Composite Indicators. *PLoS Currents*, 8. https://doi.org/10.1371/currents.dis.453df025e34b682e9737f95070f9b970

Bello, O., Bustamante, A., & Pizarro, P. (2021). *Planning for disaster risk reduction within the framework of the 2030 Agenda for Sustainable Development.* https://repositorio.cepal.org/bitstream/handle/11362/46639/1/S2000452_en.pdf

Birkmann, J., Jamshed, A., McMillan, J. M., Feldmeyer, D., Totin, E., Solecki, W., Ibrahim, Z. Z., Roberts, D., Kerr, R. B., & Poertner, H.-O. (2022). Understanding human vulnerability to climate change: A global perspective on index validation for adaptation planning. *Science of the total environment*, 803, 150065. https://doi.org/10.1016/j.scitotenv.2021.150065

Bol, G. K., & van Niekerk, D. (2023). Climate Change and the Rising Disaster Risk in Africa. In S. D'Amico & F. De Pascale (Eds.), *Geohazards and Disaster Risk Reduction* (pp. 181-210). Springer, Cham. https://doi.org/10.1007/978-3-031-24541-1_10

Chmutina, K., & Von Meding, J. (2019). A dilemma of language:“Natural disasters” in academic literature. *International Journal of Disaster Risk Science*, 10, 283-292. https://doi.org/10.1007/s13753-019-00232-2

Creswell, J. W. (2014). *A concise introduction to mixed methods research*. Sage publications.

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Dasgupta, R., & Patel, P. P. (2017). Examining the physical and human dichotomy in geography: existing divisions and possible mergers in pedagogic outlooks. *Geographical Research*, 55(1), 100-120. https://doi.org/10.1111/1745-5871.12220

Dawadi, S., Shrestha, S., & Giri, R. A. (2021). Mixed-methods research: A discussion on its types, challenges, and criticisms. *Journal of Practical Studies in Education*, 2(2), 25-36. https://doi.org/10.46809/jpse.v2i2.20

Dilley, M., Chen, R. S., Deichmann, U., Lerner-Lam, A., Arnold, M., J., A., Buys, P., Kjekstad, O., Lyon, B., & Yetman, G. (2005). *Natural disaster hotspots: a global risk analysis* (Vol. 5). World Bank Publications.

Drakes, O., & Tate, E. (2022). Social vulnerability in a multi-hazard context: a systematic review. *Environmental Research Letters*, 17(3), 033001. https://doi.org/10.1088/1748-9326/ac5140

Duval, T. S., & Mulilis, J.-P. (1999). A Person-Relative-to-Event (PrE) Approach to Negative Threat Appeals and Earthquake Preparedness: A Field Study1. *Journal of Applied Social Psychology*, 29(3), 495-516. https://doi.org/10.1111/j.1559-1816.1999.tb01398.x

ECJRC. (2023). *Index for Risk Management [INFORM]*. European Commission Joint Research Center https://drmkc.jrc.ec.europa.eu/inform-index/

Eckstein, D., Hutfils, M.-L., & Winges, M. (2018). *Global climate risk index 2019: Who suffers most from extreme weather events*. Germanwatch. e.V.

Egawa, S., Jibiki, Y., Sasaki, D., Ono, Y., Nakamura, Y., Suda, T., & Sasaki, H. (2018). The correlation between life expectancy and disaster risk. *Journal of Disaster Research*, 13(6), 1049-1061. https://doi.org/10.20965/jdr.2018.p1049

Eze, E., Nwagu, E. K., & Onuoha, J. C. (2022). Nigerian teachers' self-reported climate science literacy and expressed training needs on climate change concepts: Prospects of job-embedded situative professional development. *Science Education*, 106(6), 1535-1567. https://doi.org/10.1002/sce.21743

Eze, E., Petersen, M., & Siegmund, A. (2024). Enhancing protection motivation for disaster preparedness among actors at UNESCO-designated heritage sites in Africa. *International Journal of Disaster Risk Reduction*, 109, 104599. https://doi.org/10.1016/j.ijdrr.2024.104599

Eze, E., & Siegmund, A. (2024a). Identifying disaster risk factors and hotspots in Africa from spatiotemporal decadal analyses using INFORM data for risk reduction and sustainable development. *Sustainable Development*, 1-22. https://doi.org/10.1002/sd.2886

Eze, E., & Siegmund, A. (2024b). Analyzing Important Disaster Risk Factors for Enhanced Policy Responses in Perceived at-Most-Risk African Countries. *Environments*, 11(2). https://doi.org/10.3390/environments11020027

Eze, E., & Siegmund, A. (2024c). Next-generation core competency gaps for disaster risk management and preparedness in UNESCO-designated heritage sites. *Sustainable Futures*, 8, 100239. https://doi.org/10.1016/j.sftr.2024.100239

Eze, E., & Siegmund, A. (2024d). Appraising competency gaps among UNESCO-designated heritage site actors in disaster risk reduction innovations. *Progress in disaster science*, 22, 100321. https://doi.org/10.1016/j.pdisas.2024.100321

Eze, E., & Siegmund, A. (2024e). Exploring factors of disaster preparedness in UNESCO-designated heritage sites. *Geography and Sustainability.* https://doi.org/10.1016/j.geosus.2024.04.001

Feldmann-Jensen, S., Jensen, S. J., Smith, S. M., & Vigneaux, G. (2019). The next generation core competencies for emergency management. *Journal of Emergency Management*, 17(1), 17-25. https://doi.org/10.5055/jem.2019.0393

Fontes de Meira, L., & Bello, O. (2020). *The use of technology and innovative approaches in disaster and risk management: a characterization of Caribbean countries' experiences.* https://repositorio.cepal.org/entities/publication/7fc6e401-e9e8-4745-88b6-79456bf12472

Fricker, R. D. (2008). *Sampling methods for web and e-mail surveys.* The Sage handbook of online research methods. London: Sage Publications Ltd.

Gaillard, J., Alexander, B., Becker, P., Blanchard, K., Bosher, L., Broines, F., Cadag, J., & Chmutina, K. (2019). *Power, prestige & forgotten values: A disaster studies manifesto.* Retrieved April 2 from www.ipetitions.com/petition/power-prestige-forgotten-values-a-disaster

Gaillard, J. C. (2019). Disaster studies inside out. *Disasters*, 43 Suppl 1, S7-S17. https://doi.org/10.1111/disa.12323

Garschagen, M., Doshi, D., Reith, J., & Hagenlocher, M. (2021). Global patterns of disaster and climate risk—an analysis of the consistency of leading index-based assessments and their results. *Climatic change*, 169(1-2), 11. https://doi.org/10.1007/s10584-021-03209-7

Garschagen, M., Hagenlocher, M., Comes, M., Dubbert, M., Sabelfeld, R., Lee, Y. J., Grunewald, L., Lanzendörfer, M., Mucke, P., & Neuschäfer, O. (2016). *World risk report 2016*. (3946785026). Berlin: Bündnis Entwicklung Hilft and UNU-EHS Retrieved from http://collections.unu.edu/view/unu:5763

Ginige, K. (2011). Disaster Risk Reduction and its Relationship with Sustainable Development. In Amarantuga, D. & Haigh, R. *Post-Disaster Reconstruction of the Built Environment*, 287. https://doi.org/10.1002/9781444344943

Hagelsteen, M., & Burke, J. (2016). Practical aspects of capacity development in the context of disaster risk reduction. *International Journal of Disaster Risk Reduction*, 16, 43-52. https://doi.org/10.1016/j.ijdrr.2016.01.010

Haque, M. S. (2022). Inductive and/or deductive research designs. In M. R. Islam, N. A. Khan, & R. Baikady (Eds.), *Principles of social research methodology* (pp. 59-71). Springer. https://doi.org/10.1007/978-981-19-5441-2_5

Hølleland, H., Hamman, E., & Phelps, J. (2019). Naming, shaming and fire alarms: the compilation, development and use of the List of World Heritage in Danger. *Transnational Environmental Law*, 8(1), 35-57. https://doi.org/10.1017/S2047102518000225

Holloway, A. (2012). Disaster risk in Africa: Dynamic discourse or dysfunctional dialogue. In E. Macamo, L. Bloemertz, M. Doevenspeck, & D. Müller-Mahn (Eds.), *Risk and Africa: multi-disciplinary empirical approaches* (pp. 17-34). Beiträge zur Afrikaforschung.

Holvoet, N., & Inberg, L. (2014). Gender sensitivity of Sub-Saharan Africa National Adaptation Programmes of Action: findings from a desk review of 31 countries. *Climate and Development*, 6(3), 266-276. https://doi.org/10.1080/17565529.2013.867250

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, 15(9), 1277-1288. https://doi.org/10.1177/1049732305276687

Hu, H., Lei, T., Hu, J., Zhang, S., & Kavan, P. (2018). Disaster-mitigating and general innovative responses to climate disasters: Evidence from modern and historical China. *International Journal of Disaster Risk Reduction*, 28, 664-673. https://doi.org/10.1016/j.ijdrr.2018.01.022

Imperiale, A. J., & Vanclay, F. (2016). Experiencing local community resilience in action: Learning from post-disaster communities. *Journal of Rural Studies*, 47, 204-219. https://doi.org/10.1016/j.jrurstud.2016.08.002

Imperiale, A. J., & Vanclay, F. (2021). Conceptualizing community resilience and the social dimensions of risk to overcome barriers to disaster risk reduction and sustainable development. *Sustainable Development*, 29(5), 891-905. https://doi.org/10.1002/sd.2182

Izumi, T., Shaw, R., Djalante, R., Ishiwatari, M., & Komino, T. (2019). Disaster risk reduction and innovations. *Progress in disaster science*, 2, 100033. https://doi.org/10.1016/j.pdisas.2019.100033

Kankam, P. K. (2019). The use of paradigms in information research. *Library & Information Science Research*, 41(2), 85-92. https://doi.org/10.1016/j.lisr.2019.04.003

Kaslow, N. J., Finklea, J. T., & Chan, G. (2018). Personality Assessment: A Competency-Capability Perspective. *Journal of Personality Assessment*, 100(2), 176-185. https://doi.org/10.1080/00223891.2017.1381970

Kelman, I., Gaillard, J. C., & Mercer, J. (2015). Climate Change's Role in Disaster Risk Reduction's Future: Beyond Vulnerability and Resilience. *International Journal of Disaster Risk Science*, 6(1), 21-27. https://doi.org/10.1007/s13753-015-0038-5

Koudjom, E., Tamwo, S., & Kpognon, K. D. (2022). Does poverty increase COVID-19 in Africa? A cross-country analysis. *Health Economics Review*, 12(1), 51. https://doi.org/10.1186/s13561-022-00399-3

Koutsopoulos, K. C. (2011). Changing paradigms of geography. *European Journal of Geography*, 2(1), 54 - 75. https://www.eurogeojournal.eu/index.php/egj/article/view/33.

Kuglitsch, M. M., Pelivan, I., Ceola, S., Menon, M., & Xoplaki, E. (2022). Facilitating adoption of AI in natural disaster management through collaboration. *Nature communications*, 13(1), 1579. https://doi.org/10.1038/s41467-022-29285-6

Kuhn, T. (1970). The nature of scientific revolutions. *Chicago: University of Chicago*, *197*(0).

Le Dé, L., & Gaillard, J. (2022). Whose views matter? For a pluralistic approach to understanding disasters. In *Defining disaster* (pp. 123-139). Edward Elgar Publishing. https://doi.org/10.4337/9781839100307.00018

Lehdonvirta, V., Oksanen, A., Räsänen, P., & Blank, G. (2021). Social Media, Web, and Panel Surveys: Using Non-Probability Samples in Social and Policy Research. *Policy & Internet*, 13(1), 134-155. https://doi.org/10.1002/poi3.238

Lindbom, H., Hassel, H., Tehler, H., & Uhr, C. (2018). Capability assessments–How to make them useful for decision-making. *International Journal of Disaster Risk Reduction*, 31, 251-259. https://doi.org/10.1016/j.ijdrr.2018.05.009

Lindbom, H., Tehler, H., Eriksson, K., & Aven, T. (2015). The capability concept–On how to define and describe capability in relation to risk, vulnerability and resilience. *Reliability Engineering & System Safety*, 135, 45-54. https://doi.org/10.1016/j.ress.2014.11.007

Lowenthal, D. (2013). Natural and cultural heritage. In D. Lowenthal & K. Olwig (Eds.), *The Nature of Cultural Heritage, and the Culture of Natural Heritage* (pp. 79-90). Routledge. https://doi.org/10.4324/9781315869674

Mahadevan, J. (2023). What connects positivism and interpretivism in cross-cultural management studies: Genealogy as a method for re-ordering disciplinary knowledge. *International Journal of Cross Cultural Management*. https://doi.org/10.1177/14705958231223874

Manatsa, D., & Sakala, L. (2023). Harnessing Scientific Knowledge and Technological Innovation for Disaster Risk Reduction (DRR) in Sub-Saharan Africa-Case of Social Media. In H. Tatano & A. Collins, *Proceedings of the 4th Global Summit of Research Institutes for Disaster Risk Reduction Singapore*. GSRIDRR 2019. Disaster and Risk Research: GADRI Book Series. https://doi.org/10.1007/978-981-19-5566-2_7

Marin-Ferrer, M., Vernaccini, L., & Poljansek, K. (2017). *Index for Risk Management INFORM Concept and Methodology Report*. Publications Office of the European Union, Joint Research Centre

Mizutori, M., & Guha-Sapir, D. (2020). *Human cost of disasters: An overview of the last 20 years (2000-2019)*. Belgium and Switzerland: Centre for Research on the Epidemiology of Disasters (CRED) and United Nations Office for Disaster Risk Reduction (UNDRR),.

Murnane, R., Simpson, A., & Jongman, B. (2016). Understanding risk: what makes a risk assessment successful? *International Journal of Disaster Resilience in the Built Environment*, 7(2), 186-200. https://doi.org/10.1108/IJDRBE-06-2015-0033

Ofei-Manu, P., & Didham, R. J. (2018). Disaster Risk Reduction Capacity Assessment: Conceptualizing a Systematic Capacity (Assessment) Framework for Japan. In Handbook of Disaster Risk Reduction & Management (pp. 97-138). *World Scientific*. https://doi.org/10.1142/9789813207950_0005

Ofli, F., & Imran, M. (2023). Introduction: Emerging Technologies and Innovative Applications of AI in DRR. *International Handbook of Disaster Research*, 471-476. https://doi.org/10.1007/978-981-19-8388-7_210

Orimoloye, I. R., Belle, J. A., & Ololade, O. O. (2021). Exploring the emerging evolution trends of disaster risk reduction research: a global scenario. *International Journal of Environmental Science and Technology*, 18(3), 673-690. https://doi.org/10.1007/s13762-020-02847-1

Orimoloye, I. R., Ekundayo, T. C., Ololade, O. O., & Belle, J. A. (2021). Systematic mapping of disaster risk management research and the role of innovative technology. *Environmental Science and Pollution Research*, 28(4), 4289-4306. https://doi.org/10.1007/s11356-020-10791-3

Osuteye, E., Johnson, C., & Brown, D. (2017). The data gap: An analysis of data availability on disaster losses in sub-Saharan African cities. *International Journal of Disaster Risk Reduction*, 26, 24-33. https://doi.org/10.1016/j.ijdrr.2017.09.026

Panwar, V., & Sen, S. (2020). Disaster Damage Records of EM-DAT and DesInventar: A Systematic Comparison. *Economics of Disasters and Climate Change*, 4(2), 295-317. https://doi.org/10.1007/s41885-019-00052-0

Pavlova, I., Fassoulas, C., Watanabe, M., Canet, C., & Cupa, P. (2019). *UNESCO designated sites—natural and cultural heritage sites as platforms for awareness raising.* Contributing paper to GAR.

Pavlova, I., Makarigakis, A., Depret, T., & Jomelli, V. (2017). Global overview of the geological hazard exposure and disaster risk awareness at world heritage sites. *Journal of Cultural Heritage*, 28, 151-157. https://doi.org/10.1016/j.culher.2015.11.001

Pavlova, I., Yasukawa, S., Dousseron, A., & Jomelli, V. (2021). Landslides at UNESCO-Designated Sites. In K. Sassa, M. Mikoš, S. Sassa, P. T. Bobrowsky, K. Takara, & K. Dang (Eds.), *Understanding and Reducing Landslide Disaster Risk: Volume 1 Sendai Landslide Partnerships and Kyoto Landslide Commitment* (pp. 413-419). Springer International Publishing. https://doi.org/10.1007/978-3-030-60196-6_33

Peduzzi, P., Dao, H., Herold, C., & Mouton, F. (2009). Assessing global exposure and vulnerability towards natural hazards: the Disaster Risk Index. *Natural Hazards and Earth System Sciences*, 9(4), 1149-1159. https://doi.org/10.5194/nhess-9-1149-2009

Rahman, A.-u., & Fang, C. (2019). Appraisal of gaps and challenges in Sendai framework for disaster risk reduction priority 1 through the lens of science, technology and innovation. *Progress in disaster science*, 1, 100006. https://doi.org/10.1016/j.pdisas.2019.100006

Raju, E., Boyd, E., & Otto, F. (2022). Stop blaming the climate for disasters. *Communications Earth & Environment*, 3(1). https://doi.org/10.1038/s43247-021-00332-2

Ramli, M. W. A., Alias, N. E., Mohd Yusof, H., Yusop, Z., & Taib, S. M. (2021). Development of a local, integrated disaster risk assessment framework for Malaysia. *Sustainability*, 13(19), 10792. https://doi.org/10.3390/su131910792

Ranganathan, P., & Aggarwal, R. (2020). Study designs: Part 7 - Systematic reviews. *Perspectives in Clinical Research*, 11(2), 97-100. https://doi.org/10.4103/picr.PICR_84_20

Raymond, C. M., Brown, G., & Robinson, G. M. (2011). The influence of place attachment, and moral and normative concerns on the conservation of native vegetation: A test of two behavioural models. *Journal of Environmental Psychology*, 31(4), 323-335. https://doi.org/10.1016/j.jenvp.2011.08.006

Rogers, R. W. (1975). A Protection Motivation Theory of Fear Appeals and Attitude Change1. *The Journal of Psychology*, 91(1), 93-114. https://doi.org/10.1080/00223980.1975.9915803

Samaraweera, H. U. S. (2024). Exploring complexities of disaster risk and vulnerability: Everyday lives of two flood-affected communities in Sri Lanka. *Sustainable Development*, 32(2), 1376-1385. https://doi.org/10.1002/sd.2723

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., Burroughs, H., & Jinks, C. (2018). Saturation in qualitative research: exploring its conceptualization and operationalization. *Quality & Quantity*, 52(4), 1893-1907. https://doi.org/10.1007/s11135-017-0574-8

Scott, M. (2020). *Climate change, disasters and the refugee convention*. Cambridge University Press. https://doi.org/10.1017/9781108784580.005

Shaw, R. (2020). Thirty Years of Science, Technology, and Academia in Disaster Risk Reduction and Emerging Responsibilities. *International Journal of Disaster Risk Science*, 11(4), 414-425. https://doi.org/10.1007/s13753-020-00264-z

Shaw, R., Izumi, T., & Shiwaku, K. (2018). Science and technology in disaster risk reduction in Asia: Post-Sendai developments. In R. Shaw, K. Shiwaku, & T. Izumi (Eds.), *Science and Technology in Disaster Risk Reduction in Asia* (pp. 3-16). Academic Press. https://doi.org/10.1016/B978-0-12-812711-7.00001-8

Shaw, R., & Kanbara, S. (2022). Science, Technology, Innovation and Sendai Framework for Disaster Risk Reduction. In S. Kanbara, R. Shaw, N. Kato, H. Miyazaki, & A. Morita (Eds.), So*ciety 5.0, Digital Transformation and Disasters: Past, Present and Future* (pp. 15-23). Springer Nature Singapore. https://doi.org/10.1007/978-981-19-5646-1_2

Shi, P., Ye, T., Wang, Y., Zhou, T., Xu, W., Du, J., Wang, J. a., Li, N., Huang, C., Liu, L., Chen, B., Su, Y., Fang, W., Wang, M., Hu, X., Wu, J., He, C., Zhang, Q., Ye, Q., . . . Okada, N. (2020). Disaster Risk Science: A Geographical Perspective and a Research Framework. *International Journal of Disaster Risk Science*, 11(4), 426-440. https://doi.org/10.1007/s13753-020-00296-5

Stern, P. C. (2000). New environmental theories: toward a coherent theory of environmentally significant behavior. *Journal of social issues*, 56(3), 407-424. https://doi.org/10.1111/0022-4537.00175

Swedberg, R. (2020). Exploratory research. In C. Elman, J. Gerring, & J. Mahoney (Eds.), *The production of knowledge: Enhancing progress in social science* (Vol. 2, pp. 17-41). https://doi.org/10.1017/9781108762519.002

Tasantab, J. C., Gajendran, T., Owi, T., & Raju, E. (2023). Simulation-based learning in tertiary-level disaster risk management education: a class-room experiment. *International Journal of Disaster Resilience in the Built Environment*, 14(1), 21-39. https://doi.org/10.1108/IJDRBE-04-2021-0045

Tay, H. L., Banomyong, R., Varadejsatitwong, P., & Julagasigorn, P. (2022). Mitigating risks in the disaster management cycle. *Advances in Civil Engineering*, 2022(1), 7454760. https://doi.org/10.1155/2022/7454760

Thow, A., Poljansek, K., Nika, A., Marzi, S., Dalla, V. D., Galimberti, L., & Manili, C. (2024). *INFORM report 2024: 10 years of INFORM: shared evidence for managing crises and disasters*. (9268117754). European Commission, Joint Research Centre Retrieved from https://data.europa.eu/doi/10.2760/555548

UNESCO. (2021). Operational guidelines for the implementation of the World Heritage Convention. In: World Heritage Committee. https://whc.unesco.org/en/guidelines/

UNGA. (2016). *Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction.* The United Nations. Retrieved October 29 2023 from https://www.preventionweb.net/files/50683_oiewgreportenglish.pdf

UNISDR. (2015). Sendai framework for disaster risk reduction 2015–2030. United Nations International Strategy for Disaster Reduction Retrieved from https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030/

van Riet, G. (2021). The nature–culture distinction in disaster studies: the recent petition for reform as an opportunity for new thinking? *International Journal of Disaster Risk Science*, 12, 240-249. https://doi.org/10.1007/s13753-021-00329-7

Visser, H., De Bruin, S., Martens, A., Knoop, J., & Ligtvoet, W. (2020). What users of global risk indicators should know. *Global Environmental Change*, 62, 102068. https://doi.org/10.1016/j.gloenvcha.2020.102068

Ward, P. J., Blauhut, V., Bloemendaal, N., Daniell, J. E., de Ruiter, M. C., Duncan, M. J., Emberson, R., Jenkins, S. F., Kirschbaum, D., & Kunz, M. (2020). Natural hazard risk assessments at the global scale. *Natural Hazards and Earth System Sciences*, 20(4), 1069-1096. https://doi.org/10.5194/nhess-20-1069-2020

Welchman, J. (2016). Environmental versus Natural Heritage Stewardship: Nova Scotia's Annapolis River and the Canadian Heritage River System. In G. H. D. M. Hourdequin (Ed.), *Restoring Layered Landscapes: History, Ecology and Culture* (pp. 112-132). https://doi.org/10.1093/acprof:oso/9780190240318.003.0007

Welle, T., & Birkmann, J. (2015). The world risk index–an approach to assess risk and vulnerability on a global scale. *Journal of Extreme Events*, 2(01), 1550003. https://doi.org/10.1142/S2345737615500037

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: a reference framework for academic program development. *Sustainability science*, 6, 203-218. https://doi.org/10.1007/s11625-011-0132-6

Yu, T.-K., Lin, F.-Y., Kao, K.-Y., & Yu, T.-Y. (2019). Encouraging environmental commitment to sustainability: An empirical study of environmental connectedness theory to undergraduate students. *Sustainability*, 11(2), 342. https://doi.org/10.3390/su11020342

Zhu, X., & Shang, X. (2024). Positioning as discursive struggle for equity: a critical discourse analysis of the Nationally Determined Contributions (NDCs) of African countries. *Critical discourse studies*, 21(2), 218-233. https://doi.org/10.1080/17405904.2023.2197608

Part II: Publications

1

"We must learn from the past to better prepare for the future." ~ Amanda Ripley

II.1. Identifying disaster risk factors and hotspots in Africa from spatiotemporal decadal analyses using INFORM data for risk reduction and sustainable development

Abstract

The incidence and magnitude of hazards in Africa are escalating. Extant knowledge base of disaster risk (DR) trends, factors, and hotspots is lacking for the continent. Here we applied random forest machine learning regressions, spatial stratified heterogeneity, and hotspot analyses on INFORM data to identify DR patterns, factors and interactions, and notable risk hotspots. We show that although DR is generally decreasing in Africa, the Eastern, Southern, and Western regions record increasing DR. Physical exposure to floods, epidemics, and violent conflicts are hazard drivers of DR in Africa. Other significant DR drivers are mostly clustered under vulnerable groups and poor infrastructural coping capacities. Human hazards interact with other factors, exhibiting the highest influences on DR. Precisely, 19 out of 53 African countries in this study are DR hotspots. Eritrea is identified as a new hotspot. Targeted policies, resilience building, vulnerability reduction measures and comprehensive sustainability-infused solutions are required for DR reduction and sustainable development in Africa.

Keywords: Africa; disaster risk assessment; disaster risk reduction; resilience; sustainable development; vulnerability

II.1.1. Introduction

The prevalence of both natural and human-induced hazards in Africa has shown a notable increase (Aliyu, 2015). Hazards, when compounded by vulnerability or insufficient coping capabilities, often culminate in disasters characterized by substantial loss of lives and livelihoods (Raju et al., 2022). An overlooked yet crucial aspect in understanding disasters revolves around the evolution of disaster terminology. The distinction between 'unnatural' disasters in earlier literature (O'Keefe et al., 1976; Wisner et al., 2004) prompts a clear differentiation between hazards and disasters throughout this study. Hazards encompass specific phenomena, whether natural or human-induced, capable of instigating adverse socioeconomic and environmental impacts, including fatalities or injuries. On the other hand, disasters manifest as significant disturbances within a community or society, brought about by the convergence and interactions of hazardous events, exposure, vulnerability, and coping capacity (United Nations General Assembly [UNGA], 2016). Thus, efforts to mitigate disasters, must, according to Rahman and Fang (2019), be based on a comprehensive understanding of all these facets.

A comprehensive report by Mizutori and Guha-Sapir (2020) reveals a stark rise in both the frequency and severity of global disaster events. They captured disaster events as surging by 74.48% from 4212 events in the period between 1980 and 1999 to 7348 events from 2000 to 2019, with attendant losses of human lives, livelihoods, and ecosystems, amounting to trillions of dollars. These disaster-induced losses are inimical to the achievement of global sustainability frameworks such as the Agenda 2030 and the Sendai Framework for Disaster Risk Reduction [SFDRR] (United Nations International Strategy for Disaster Reduction [UNISDR], 2015). The fundamental goal of disaster risk reduction (DRR), as outlined by UNGA (2016), is to prevent the emergence of new disaster risks (DR), mitigate existing ones, and manage any residual risks to improve societal resilience and the achievement of sustainable development. It is noteworthy that Wen et al. (2023) describe the evolution of the concept of DRR through three phases in the 1990s, 2000s, and 2010s, featuring key paradigms of disaster management, risk management, and resilience management and development. Thus, the current paradigm underscores the critical link between enhancing resilience and sustainable development.

The concepts of resilience and development remain subjects of contention, necessitating clarification for collective actions (Park, 2023). In this study, resilience is employed as a rallying call, following Park (2023), to denote the outcomes of disaster risk management (DRM) and DRR initiatives. It emphasizes the fortification of a community or society's structures and functional capacities, enabling them to withstand, assimilate, adjust to, adapt, transform, and swiftly recover from hazard impacts (UNGA, 2016). Such framing of resilience by UNGA (2016) is likely to be understood as the absence of vulnerability or susceptibility of a community to damages from hazards. In fact, prior studies, such as Cardona et al. (2012) and Ismail-Zadeh (2022), highlight vulnerability and exposure as primary drivers of disasters, with natural hazards acting as triggers, and climate change intensifying them. Conversely, other studies like Imperiale and Vanclay (2016,2021), elucidate that the absence of resilience is not solely characterized by vulnerability, as even highly vulnerable communities possess substantial resources contributing to their resilience during crises and disasters. Similarly, Lavell et al. (2012) assert that the inadequacy of capacity is but one dimension within the context of overall vulnerability. This warrants a focus on not just the vulnerability levels of communities but also their resilience levels while considering the multidimensionality of these concepts.

Multiple dimensions of disasters numbering six have been synthesized by Imperiale and Vanclay (2021) to include the: (i) nature and attributes of the hazard itself; (ii) social aspects of risks and impacts (including distribution, perception, and experiences); (iii) underlying societal conditions and factors preceding disasters; (iv) capacity of local individuals to learn from past failures and disasters to facilitate sustainability; (v) underlying principles, objectives, and approaches embedded within DRM; and (vi) efficacy of social processes, services, and support systems available to a community prior to and post-disasters. The complexities inherent in disasters stem from a complex interplay of social, environmental, and governance factors, significantly amplifying their impact. Such amplification often leads to disparities in both the distribution and potential impacts of disasters. Previous research, as highlighted by Imperiale and Vanclay (2021), and findings from Machlis et al. (2022), attribute these disparities to the profound social dimensions of vulnerability and varying levels of coping abilities prevalent across diverse regions.

Africa, in particular, stands exceptionally vulnerable to the ramifications of natural hazards. Bari and Dessus (2022) identify a total of 13 African countries out of the 15 most vulnerable countries globally. Hazardous events like droughts and floods have further exacerbated poverty in the continent, causing a decline in GDP by 0.7% and 0.4% respectively (Bari & Dessus, 2022). The escalation of poverty suggests a likely simultaneous increase in vulnerabilities across the region. Moreover, a report from The Africa Center for Strategic Studies (2022) reveals a consistent rise in the population affected by disasters, with projections indicating a potential doubling by 2050, reaching nearly 2.5 billion disaster-affected individuals. This concerning trajectory is closely linked to urbanization in hazard-prone regions and increased hazard frequencies driven by climate change (Yaghmaei, 2019). Therefore, tailored DRR strategies are imperative, with a focus on reducing vulnerability dimensions and intentionally improving resilience across different regions within Africa.

Given disparities in disaster distribution across regions, it's imperative to evaluate these variations across countries within Africa, the continent most vulnerable to such challenges. Surprisingly, no prior study, to our knowledge, has delved into this crucial area. Hence, our study pioneers the application of multiple spatial statistical analyses, examining a decade's worth of data encompassing 53 African countries. This comprehensive investigation offers fresh perspectives on national-level DR patterns, trends, and focal points, employing spatiotemporal approaches such as spatial stratified heterogeneity (SSH), optimized hotspot and emerging hotspot analyses. Utilizing a meticulously curated INFORM dataset, we consider three fundamental dimensions: hazard & exposure, vulnerability, and coping capacity, consisting of six categories and 18 components—largely aligned with dimensions outlined by Imperiale and Vanclay (2021) barring one aspect (i.e., social aspects of risks and impacts). Our method hinges on empirical analysis but bears practical implications. By presenting nuanced insights into historical DR trends, we aim to furnish data-driven recommendations conducive to directing DRR efforts across the region. Moreover, our exploration of emerging hotspots serves as robust evidence to identify areas necessitating intervention priorities for mitigating DR.

II.1.2. Conceptual framework of the study

II.1.2.1. Disaster risks, DRR and sustainable development

Natural phenomena, including volcanic eruptions, precipitation patterns resulting in floods and droughts, epidemics, and climatic trends, often transform into so-called natural disasters. While these events, termed hazards, according to (Kelman et al., 2016) are frequently essential for the environment and society, their catastrophic outcomes arise from human-induced vulnerabilities, eroding the natural essence of disasters. Hence, vulnerabilities created by social processes render these events disastrous, necessitating a deeper enquiry. Bailey (2022) simplifies the disaster concept, highlighting hazards and the social system as its fundamental variables.

Disasters, stemming from natural hazards, exert profound impacts on development. They exacerbate vulnerabilities, weaken resilience, and strain coping mechanisms (Pal et al., 2021). Furthermore, Bendimerad (2003) enumerates extensive damages to the environment, economy, and human capital, leading to disruptions in developmental programs. Disaster risks (i.e., different kinds of potential losses), emerge from the convergence of hazards, exposure, vulnerabilities, and coping capacities (Imperiale & Vanclay, 2021; Raju et al., 2022; Trogrlić et al., 2022), necessitating comprehensive consideration in DRR strategies. As natural hazards are uncontrollable, focusing on vulnerabilities and coping capacities becomes imperative (Ginige, 2011). Sometimes, vulnerability concepts are insufficiently covered in DR literature (Zhou et al., 2015).

Vulnerability, according to Birkmann et al. (2006), comprises susceptibility and coping capacity, which embodies weaknesses affecting community well-being, often intensified by social risks (Imperiale & Vanclay, 2021; Samaraweera, 2023). Coping capacities, vital for recovery, entail mechanisms that shape or challenge recovery in the aftermath of disasters (Birkmann & Wisner, 2006). Thus, lack of coping capacity is also vulnerability. However, rectifying vulnerabilities doesn't guarantee increased coping capacity, as existing strengths within vulnerable communities are often overlooked (Samaraweera, 2023). Recent literature emphasizes vulnerability as the underlying cause of disasters. Kelman (2015) advocates for acknowledging vulnerability as the principal cause of disasters and highlights its significance in global policy frameworks. Moreover, Ginige (2011) views vulnerability as a controllable element within disasters, suggesting that managing vulnerabilities is crucial in disaster mitigation.

However, Samaraweera (2023) criticizes the framing of vulnerability, which often equates it with weakness, incapability, and poverty, arguing that such a portrayal overlooks its multifaceted nature, encompassing socio-economic, political, and cultural dimensions. Therefore, addressing vulnerability comprehensively requires a holistic approach considering these diverse factors. Drakes and Tate (2022) delineate social aspects determining vulnerability, including demographics, land tenure, living conditions, and socio-economic status. Hence, specific aspects of vulnerability to be tackled in any community, region or state are known. Also, measures to address vulnerability primarily involve social interventions, albeit supplemented occasionally by technical measures (Kelman et al., 2016). Holistically addressing factors contributing to vulnerability becomes crucial, particularly in policies and actions (Bendimerad, 2003).

Unfortunately, there is a lack of studies presenting the trends and levels of vulnerability in African countries. The attempt to assess vulnerability in Africa by Ahmadalipour and Moradkhani (2018) was limited to droughts. Drakes and Tate (2022) confirm that current research examining social vulnerabilities in lower-income nations tends to focus on specific localized areas, limiting the identification of vulnerability factors across wider spheres. Furthermore, insights derived from scientific studies conducted in middle- and high-income countries may not be directly applicable or transferable to lower-income nations (Drakes & Tate, 2022). This creates a need for a comprehensive understanding of vulnerability in low-income nations, such as Africa, to provide a research representation necessary for designing sustainable and impactful interventions towards vulnerability reduction. Lower-income economies can cope less with hazards, as they lack resources and infrastructure for preparedness (Abdel Hamid et al., 2020). Moreover, disaster losses extend a vicious cycle of poverty (Hallegatte et al., 2020; Salvucci & Santos, 2020).

Coping capacities are integral prerequisites for reduced vulnerability and resilience. Recommending the improvement of living standards and protection from hazards for increased resilience, Naheed (2021) defines resilience as the stability and persistence of social systems, involving the enhancement of adaptive capacities through the provision of relevant assets and resources for individuals, communities, or states. Thus, initiatives that strengthen societies to withstand the impact of and cope in the face of disasters will reduce their susceptibility. These initiatives should include capacity building and resource provisions (Acharibasam & Datta, 2023). As a crucial factor for disaster recovery and adaptation, Marin et al. (2021) advocate for the inclusion of such resilience components in DR assessments. Notably, acute shortage of skilled practitioners have been identified as a source of delay in translating good policies into actions (Bang, 2014, 2022; Becker & van Niekerk, 2015). Furthermore, Keating et al. (2017) suggest that resilience provides an opportunity to address interconnected social and ecological aspects of DR and development.

Designing effective resilience initiatives should be preceded by a deep understanding of various needs, concerns, contexts, and vulnerability components. Subroto and Datta (2023) present such understanding as a prerequisite for disaster governance and resilience. In addition, McBean and Rodgers (2010) advocate for the establishment of national systems, infrastructure, and social networks to bolster resilience, enabling countries to better absorb the impact of natural hazards and thwart their progression into severe disasters. Therefore, the preparedness of nations to mitigate hazards and prevent their escalation into disasters requires strengthening resilience. Consequently, resilience efforts should not be regarded as singular actions but as ongoing processes. Kapucu et al. (2013) urge for continuous, coordinated local planning for resilience as vital for ensuring sustainability. Local planning plays a crucial role in building resilience, as Chipangura et al. (2017) highlight that communities are the focal point of DR concerns. Consequently, reducing vulnerabilities and exposure levels at the community level stands out as the most effective approach to DRR (Jafari et al., 2018; Zhou et al., 2015). Notably, prior research, such as Bang (2014) and Aka et al. (2017), critiques top-down hierarchical structures for mitigating disasters, advocating instead for community-driven bottom-up approaches. Additionally, Jiménez-Aceituno et al. (2020) suggest that proper DRR governance approaches can simultaneously advance both DRR and sustainable development objectives.

The literature provides evidence that implementing DRR measures, such as reducing hazard exposure and vulnerability levels, can bolster resilience, subsequently advancing the attainment of sustainable development. According to Bello et al. (2021), disasters' consequences are so profound that development cannot occur sustainably without resilience being an inherent component of development policies. The benefits derived from resilience in managing disasters are intrinsically linked to development. For instance, as highlighted by Naheed (2021), resilience leads to a decrease in fatalities during disasters, diminishes property damages, and safeguards socio-ecological systems. These observed advantages align with the economic, social, and environmental aspects of sustainable development. Furthermore, Keating et al. (2017) previously conceptualized resilience as the capability of a system, community, or society to pursue its social, ecological, and economic development objectives while effectively managing DR in a mutually reinforcing manner.

Thus, the widely recognized pillars of sustainable development are captured within the concept of resilience and underscore the synergy between DRR and sustainable development across various domains, encompassing social, economic, and environmental dimensions. Imperiale and Vanclay (2023) establish an explicit connection between DRR, sustainable development, and resilience while emphasizing wellbeing improvement, resources, services, capacities, and skills enhancement as the key to achieving DRR, resilience, and sustainable development. Similarly, Naheed (2021) contends that strategies and investments in DRR are significantly tied to reducing poverty and equitably enhancing social foundations, bearing in mind the needs of future generations. Alike, Akanle et al. (2022) describe poverty as a major concern for development and the success of the SDGs. Moreover, Ginige (2011) asserts that reducing vulnerability stands as the central objective of DRR within the framework of sustainable development.

The intricate relationship between DRR, vulnerability reduction, resilience building, and sustainable development requires a careful policy approach to avoid detrimental outcomes. Previous research like Thomalla et al. (2018) highlights the failure of DRR research to acknowledge and address how developmental processes contribute to the fundamental causes of disasters. Thus, questions arise as to what development would solve, rather than exacerbate, the problem of disasters. For instance, earlier research by Naheed (2021) established a connection between unplanned urbanization and heightened vulnerability levels. Therefore, inappropriate development practices tend to amplify, rather than diminish, vulnerability to DR. Acknowledging this reality, Thomalla et al. (2018) advocate for transformative changes towards equitable, resilient, and sustainable development. They propose a need to challenge prevailing values and objectives in existing development practices, critically evaluate the deficiencies in development and DRR approaches, and advocate for radical policy shifts and systemic changes in social systems to mitigate risks and counteract unsustainable development.

Therefore, policy gaps emerge concerning DRR and sustainable development. According to Kelman (2015), comprehensive DRR frameworks ought to effectively balance the concepts of hazards, vulnerability, and resilience. Similarly, Imperiale and Vanclay (2023) suggest that development policies, plans, programs, and projects should acknowledge, involve, and empower the processes of social learning and sustainability transformation, which are fundamental to fostering proactive resilience. Advancing research, policy, and practice in addressing vulnerability and resilience for sustainable development mandates a clear understanding of the complexities involved. Kelman (2015) argue that comprehending the long-term causes and consequences of vulnerability and resilience requires insights gleaned from various sources and contexts to develop diverse intervention strategies. Moreover, policies driven by information are imperative to progress both DRR efforts and sustainable development (Chen et al., 2021). Further gaps exist in the lack of long-term analyses of DR in African countries, encompassing the various components involved. This dearth of analysis could potentially hinder the continent's ability to enhance resilience for preparedness and DRR, which are crucial elements for advancing towards risk-informed sustainable development.

Previous continental studies in Africa have primarily focused on two major hazards: floods and droughts. Ahmadalipour and Moradkhani (2018) conducted an assessment that evaluated historical drought vulnerability and projected this vulnerability until the end of the century. They identified Egypt, Tunisia, and Algeria as the least vulnerable countries to drought, contrasting Chad, Niger, and Malawi as the most vulnerable in Africa. Similarly, Li et al. (2016) identified Ethiopia, Kenya, Somalia, Tanzania, Nigeria, Libya, and Sudan as countries prone to floods in Africa. They highlighted runoff, per capita GDP, population, and urbanization rate as significant vulnerability factors influencing spatial disparities related to flooding. However, studies encompassing hazards, vulnerability, and coping capacities as interconnected components of disasters are scarce, prompting the necessity for this study. Our research aims to assess historical DR spanning from 2012 to 2022. The objective is to reveal trends, pinpoint significant variables driving these trends, and identify hotspots. Within hotspots, as indicated by Shi et al. (2016), the occurrences of hazards surpass coping capacities, resulting in increased vulnerabilities. Furthermore, Szabo et al. (2016) emphasize that the failure to monitor hotspots could impede progress in both sustainable development initiatives and the achievement of the SDGs.

II.1.2.2. The Index for Risk Management (INFORM) Framework

The INFORM is a risk model that encompasses three crucial dimensions of hazards & exposure, vulnerability, and lack of coping capacity, consistent with disaster literature. According to the Joint Research Centre [JRC] (2023), physical exposure and severity of specific natural and human-induced hazards are equally weighted and aggregated to compose the Hazard and Exposure dimension. Under the vulnerability dimension, socio-economic vulnerability and vulnerable groups are the components considered in the determination of the final DR index (Figure 1). Lastly, the lack of coping capacity dimension incorporates DRR programs, emphasis on mitigation and preparedness, emergency response, and recovery capabilities of countries' governments.

Therefore, the Joint Research Centre (JRC) of the European Commission developed the composite INFORM model comprising 53 indicators to gauge factors of global humanitarian crises and DR, in support of initiatives like the SFDRR, 17 SDGs and the global resilience agenda (Marin-Ferrer et al., 2017). The components that make up the three dimensions of the INFORM model have been carefully selected and curated based on scientific literature justification, robustness, transparency, reliability, global consistency, and scalability (JRC, 2023). The multiplicative equation (Equation 1) emphasizes the equal treatment of the three dimensions—hazards & exposure, vulnerability, and lack of coping capacity—within the INFORM model to generate the resulting DR index, usually overall risk scores out of 10 per country (JRC, 2023).

$$\text{Risk} = \text{Hazard \& Exposure}^{1/3} \times \text{Vulnerability}^{1/3} \times \text{Lack of coping capacity}^{1/3} \quad \textit{Eq. 1}$$

As the first global, open-source, and regularly updated tool providing an evidence-based approach to risk analysis, the INFORM model creates an opportunity for developing a comprehensive understanding of DR across 191 countries (Marin-Ferrer et al., 2017). The utility of the INFORM model as a long-term data pool lies in its potential to stimulate national-, regional-, or global-level proactive DRR initiatives, the priority allocation of resources and improving disaster preparedness based on historical trends. However, the absence of regional or national-scale studies employing the INFORM model within Africa at the time of writing this paper (in 2023) is a significant gap, warranting immediate attention to harness its potential benefits in the continent's DRR strategies.

Previous comparative studies, such as those by Beccari (2016), and Visser et al. (2020), have examined the INFORM model alongside other indicator-based assessments. Analyses by Visser et al. (2020) evaluated various criteria including definition precision, handling of uncertainty, data completeness, temporal alignment, and aggregation methods. The findings consistently suggest that the INFORM model demonstrates robustness, validity, reliability, and higher performance in comparison to other models in similar domains. Therefore, the robustness and superior performance of the INFORM model, as indicated by comparative studies across various reliability criteria, endorse its suitability and credibility as an effective tool for comprehensive risk assessment and informed decision-making for DRR, hence its use in this study.

The components, categories, and dimensions of the INFORM model (Figure 1) depict the comprehensive coverage of the dataset used in its development. The six categories (i.e., natural hazards, human hazards, socioeconomic vulnerability, vulnerable groups, institutional capacity, and infrastructure capacity) that make up the three dimensions (i.e., hazard and exposure, vulnerability, and lack of coping capacity) perfectly align with concepts incorporated in DR assessments. It has been widely acknowledged that hazards function as triggers for risks, and their damaging impact can vary significantly based on the level of exposure and vulnerability present in the affected regions (Marin et al., 2021). In the African context, the incidence of both natural and human-induced hazards has escalated (Aliyu, 2015). Natural hazards in Africa, while less frequent, possess the potential to yield higher fatalities and trigger greater population displacement compared to human hazards, as highlighted by Bang (2022). Within the INFORM model, physical exposure to the specified hazards is used for the computation of the natural hazard category. The

INFORM model, focusing on the human hazard aspect, incorporates present and anticipated risks associated with societal threats such as violent conflicts encompassing civil wars, unrest, high-intensity crime, and terrorism (Marin-Ferrer et al., 2017).

The inclusion of violent conflicts as human hazards is warranted, especially in light of projections by the World Bank (Corral et al., 2020) indicating that by 2030, around two-thirds of the world's extremely impoverished population will inhabit regions characterized by fragility and conflict. This projection poses a significant challenge to the global sustainability agenda encapsulated in the Sustainable Development Goals (SDGs) and threatens to impede the progress already achieved. A recent decadal analysis by Anderson et al. (2021), spanning from 2009 to 2019, reveals that violent conflicts in sub-Saharan Africa, notably in regions like South Sudan and Nigeria, exacerbated food insecurity to a greater extent than droughts or locust swarms.

Similarly, Adaawen et al. (2019) found widespread drought-related farmer–herder conflicts and water tensions to precede violent conflicts in the Sahel, Eastern, and Southern Africa. Consequently, it becomes evident that violent conflicts intensify vulnerability levels as well. Furthermore, as indicated by Caso et al. (2023), the co-occurrence of violent conflicts with disasters leads to severe consequences. They present a consistent increase in the occurrence of countries facing both armed conflict and concurrent disasters, underscoring the compounded challenges posed by these dual crises.

The INFORM model considers two primary vulnerability categories: socioeconomic vulnerability and vulnerable groups. These categories encompass aspects such as income, inequality, overall well-being, and specific groups of individuals more prone to disasters due to inherent or external circumstances. Social factors play a pivotal role in the realm of disasters and risk intensification, as asserted by Bailey (2022) and supported by studies from Samaraweera (2023) and Imperiale and Vanclay (2021). Moreover, the multiplier effect of climate change, poverty, and social insecurity, according to Scheffran et al. (2019), worsens humanitarian crises. Thus, this study's incorporation of these social factors is validated by their potential to exacerbate risks associated with disasters.

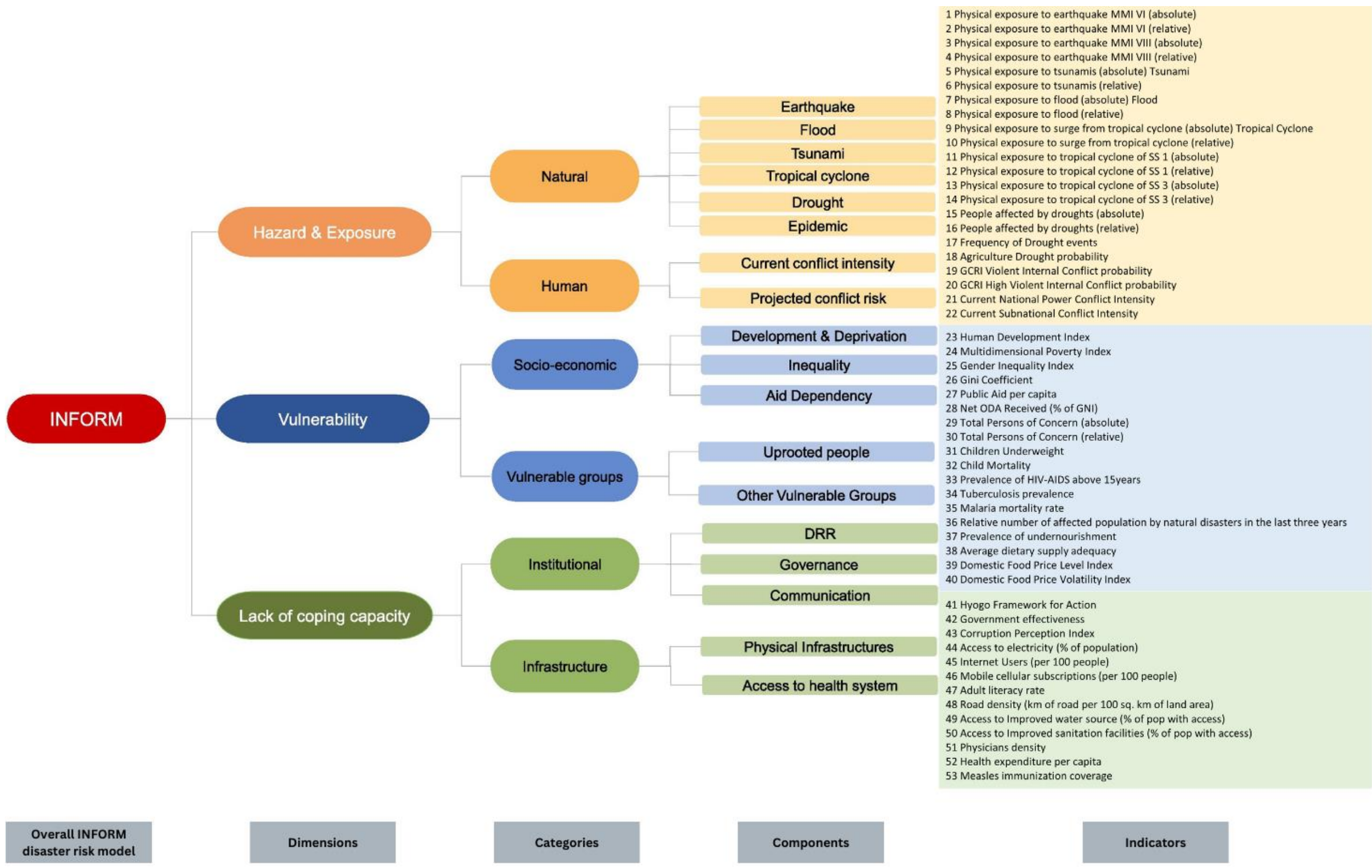

Figure II.1–1: Components of the INFORM model
Source: Modified from Marzi et al., (2021); Marin-Ferrer et al., (2017).

Notably, the indicators under both vulnerability categories closely correspond to the social aspects, excluding land tenure, outlined as critical determinants of vulnerability by Drakes and Tate (2022). The institutional and infrastructural components constitute the lack of coping capacity dimension within the INFORM model. Marin-Ferrer et al. (2017) integrated governmental initiatives aimed at enhancing resilience, disaster management, and mitigation through organized activities and existing infrastructure. Studies, including the work of McBean and Rodgers (2010), advocate for the establishment of institutional systems and robust infrastructure as crucial elements in fostering resilience and preventing the escalation of hazards into disasters.

Incorporating all variables from the INFORM model offers crucial insights that significantly contribute to disaster education and knowledge in Africa. As highlighted by Zhang and Wang (2022), there's currently a limited presence of disaster education publications or research from African countries, signaling a need for enhancement in this area. Recognizing the potential of disaster education, as suggested by AlQahtany and Abubakar (2020), holds promise in elevating disaster awareness and preparedness. This, in turn, can foster essential positive behaviors conducive to DRR and subsequently advance sustainable development.

II.1.3. Methods

II.1.3.1. Data source

We obtained the INFORM risk model output for the year 2023 from https://drmkc.jrc.ec.europa.eu/inform-index/. Relying on data spanning from 2012 to 2022, this study extracted component- and category-level data for analysis, consisting of 29 variables per annum (Table 1). Meanwhile, the overall risk index of the INFORM model served as the dependent variable for relevant analyses conducted in this study. The INFORM model is esteemed among the top three indexes in climate risk research, known for its adherence to standardized methodologies and scientific conceptual frameworks (Bornhofen et al., 2019; Garschagen et al., 2021).

Additionally, prior research has extensively evaluated the reliability and validity of the INFORM index in DR assessment. For instance, Egawa et al. (2018) underscored the credibility of the INFORM data as a representative DR index. Similarly, Birkmann et al. (2022) affirmed the dataset's reliability, highlighting a remarkable internal consistency and indicator reliability exceeding 90%, hence our adoption of this data for this study.

II.1.3.2. Data preparation

Data was obtained in clean XLS format. We then prepared two separate sets of data for the intended long-term analyses. Firstly, the mean value was calculated across the entire dataset for each variable per country within the timeframe of 2012–2022. This was used for the decadal mean analyses in the study. Subsequently, the complete dataset was compiled for each country for the decadal analyses, maintaining the original structure per variable.

II.1.3.3. Data analyses

II.1.3.3.1. Trend analyses

To examine the trends in DR, our study employed a combination of descriptive chart plots and the Mann-Kendall monotonic trend analysis method (MK). The descriptive chart plots, generated using the ggplot2 package in R version 4.2.1, were designed as scatter plots with a smoothed line to visually represent the pattern in the data. These visualizations allowed us to illustrate the observed trends effectively.

In addition to the chart plots, we conducted the MK using the Kendall package of McLeod and McLeod (2015) to rigorously assess the presence and nature of monotonic trends in the DR data. The MK, introduced by Kendall (1975), is a non-parametric statistical test specifically designed to evaluate whether values in a dataset demonstrate consistent trends of increase, decrease, or stability over time. This method is particularly advantageous as it does not rely on assumptions regarding the distribution of the data, ensuring robustness in trend analysis.

Hence, for the DR trend analyses for Africa for the period 2012–2022, we followed two major steps: first, generating descriptive chart plots through the ggplot2 package in R to visually depict patterns in the data. Secondly, we performed the MK using the Kendall package in R to statistically assess the presence and nature of monotonic trends in the DR dataset. The p-values were computed at a 5% significant level to highlight significant trends, if any.

This combined approach allowed for both visual and statistical analyses, providing a comprehensive understanding of DR trends without imposing stringent assumptions on the data's distribution. R scripts used for trend analyses are contained in the Data S1. A positive value from the output means that the trend is increasing, while a negative value means that the trend is decreasing.

Table II.1–1: Variables used in the study

Variable role	Variable name	Variable type	Purposes
Dependent variable	INFORM Risk	Overall risk level	MKTA, VIDA, VIDMA, HAS, SSHq
Independent variables	Physical exposure to earthquakes	Natural hazard	VIDA, VIDMA
	Physical exposure to floods	Natural hazard	VIDA, VIDMA
	Physical exposure to tsunamis	Natural hazard	VIDA, VIDMA
	Physical exposure to tropical cyclones	Natural hazard	VIDA, VIDMA
	Physical exposure to droughts	Natural hazard	VIDA, VIDMA
	Physical exposure to epidemics	Natural hazard	VIDA, VIDMA
	Projected Conflict Risk	Human hazard	VIDA, VIDMA
	Current Highly Violent Conflict Intensity	Human hazard	VIDA, VIDMA
	Development & Deprivation	Socioeconomic vulnerability	VIDA, VIDMA
	Inequality	Socioeconomic vulnerability	VIDA, VIDMA
	Economic Dependency	Socioeconomic vulnerability	VIDA, VIDMA
	Uprooted people	Vulnerable Groups	VIDA, VIDMA
	Health Conditions	Vulnerable Groups	VIDA, VIDMA
	Children U5	Vulnerable Groups	VIDA, VIDMA
	Recent Shocks	Vulnerable Groups	VIDA, VIDMA
	Food Security	Vulnerable Groups	VIDA, VIDMA
	Other Vulnerable Groups	Vulnerable Groups	VIDA, VIDMA
	DRR	Institutional coping capacity	VIDA, VIDMA
	Governance	Institutional coping capacity	VIDA, VIDMA
	Communication	Institutional coping capacity	VIDA, VIDMA

	Physical infrastructure	Infrastructural coping capacity	VIDA, VIDMA
	Access to healthcare	Infrastructural coping capacity	VIDA, VIDMA
Category variables	Natural Hazards	Hazard	MKTA, SSHq
	Human Hazards	Hazard	MKTA, SSHq
	Vulnerable Groups	Vulnerability	MKTA, SSHq
	Socio-Economic Vulnerability	Vulnerability	MKTA, SSHq
	Infrastructure	Coping capacity	MKTA, SSHq
	Institutional	Coping capacity	MKTA, SSHq

Notes:

MKTA = Mann-Kendall Trend Analyses

VIDA = Variable Importance Decadal Analyses

VIDMA = Variable Importance Decadal Mean Analyses

HSA = Hotspot Analyses

SSHq = Spatial Stratified Heterogeneity q-statistics

II.1.3.3.2. Variable importance analyses

This study extensively explored variables' importance through the application of random forest regression analyses. To achieve this, we employed the randomForestExplainer package, recognized for its robustness in explaining variable importance within random forest models, as developed by Paluszynska et al. (2020). The analyses were conducted using R version 4.2.1, and the R scripts utilized for these analyses are provided in the Data S1 for reference.

Our methodology encompassed a two-fold investigation, using both decadal and decadal mean data of independent and dependent variables in Table 1 for all African countries for the period 2012–2022. To identify the pivotal factors influencing DR, an unsupervised Random Forest (RF) regression consisting of 500 trees was trained. Subsequently, we assessed the distribution of minimal depth derived from the constructed forest through the application of the min_depth_distribution function.

Furthermore, various other crucial importance measures, including the number of nodes, accuracy decrease (MSE increase), Gini decrease (node purity increase), number of trees, times_a_root, and p-value, were derived. To delve deeper into the statistical aspects of the methodology we employed to determine top important DR variables in this study, Paluszynska (2017) provides extensive analysis worth exploring.

In summary, the methodology used for ascertaining important variables for both decadal and decadal mean DR factors through the randomForestExplainer package encompassed the following steps:

Step 1: Training of the data with a randomForest classifier comprising 500 trees.

Step 2: Utilizing the created forest with the min_depth_distribution function to acquire the distribution of minimal depth. A total of seven measures of importance–mean minimal depth, number of nodes, accuracy decrease (MSE increase), Gini decrease (node purity increase), number of trees, times_a_root, and p-value are obtained from our analyses and used in the next step.

Step 3: Plotting the top ten important variables alongside the distribution of minimal depth.

Step 4: Visualizing multi-way importance with mean squared error post-permutation and the increase in the node purity index (y-axis).

II.1.3.3.3 Spatial Stratified Heterogeneity (SSH) models

Spatial Stratified Heterogeneity (SSH) models serve to unravel associations between geographical attributes by comparing variations in regional and global data (Wang et al., 2010; Wang et al., 2016). We conducted our analysis leveraging the

Geographical detector tool, a widely acclaimed method for assessing the power of determinants and attributions for SSH (Song, 2021).

We sought to identify and measure the heterogeneity with spatial strata of our DR datasets, assess the coupling between factors Y and X without assuming linearity of their association, and lastly determine the interaction between explanatory factors X1 to X6 (corresponding to the six category-level variables of DR, i.e., natural hazards, human hazards, vulnerable groups, socio-economic vulnerability, Infrastructure, and institutional) and a response factor of Y (DR index).Three major steps were followed in the SSH model performed in this study:

Step 1: mapping response variable Y in strata according to X using the risk detector function;

Step 2: using the factor detector q-statistic to measure the degree of spatial stratified heterogeneity of a variable Y if Y is stratified by itself; and the determinant power of an explanatory variable X on Y if Y is stratified by X;

Step 3: employing the interaction detector to reveal whether the risk factors X1 to X6 have an interactive influence on a response variable Y.

Using the decadal mean value of the six category-level variables as X1 to X6 and the INFORM DR model as Y, we obtained three crucial results: the risk detector, factor detector (*q*-statistic), and interaction detector. The risk detector illustrates how the response factor Y varies across strata defined by X; the factor detector assesses the level of spatial stratified heterogeneity within a factor Y when Y is stratified by itself.

Furthermore, it quantifies the determinant power of an explanatory factor X on Y when Y is stratified by X. The interaction detector scrutinizes whether risk factors like X1 to X6 exhibit an interactive influence on the response factor Y. Readers seeking in-depth statistical insights into the SSH are directed to Wang et al. (2016) for further details.

II.1.3.3.4 Hotspot analyses

For our analysis, we employed two fundamental techniques, namely the optimized hotspot analyses and emerging hotspot analyses, using ArcGIS Pro version 3.0.2. The Hot Spot Analysis tool in ArcGIS employs the Getis-Ord Gi* statistic (Getis & Ord, 1992) to compute z-scores and p-values for each feature in a dataset, revealing spatial clusters where features with either high or low attribute values tend to cluster together (Esri, 2023a). Additional results from the emerging hotspot analyses incorporate hotspot bin classification based on the MK accounting for temporal dimensions of the data.

Consequently, these complementary methods contribute to identifying significant spatial patterns of DR in Africa. They highlight areas with high or low values concerning neighboring features and describe the trends of DR per country based on the DR index spanning from 2012 to 2022. This combined approach provides a comprehensive understanding of the spatial distribution and temporal trends of DR within the dataset.

These methodologies are widely acknowledged for their efficacy in pattern analysis (Khan et al., 2022) and we utilized them to unravel the spatial and temporal variations, patterns, and emerging hotspots of DR across Africa. While the optimized hotspot analysis serves to identify spatial relationships and statistically significant clusters of DR hotspots and cold spots within the African region, the emerging hotspot analysis adds a temporal dimension by scrutinizing the evolving patterns of DR per country during the study period (2012–2022). The temporal aspects of the emerging hotspot analysis enabled us to capture the dynamic nature of DR hotspots and cold spots, providing insights into the changing patterns over time in the period under consideration. Together, both analyses reveal countries that demand focused attention and urgent intervention measures.

We conducted an analysis using decadal data from the INFORM risk index covering the period from 2012 to 2022, examining yearly data points for 53 countries. This involved utilizing 530 valid input features to perform permutations and clustering, identifying significantly high and low clusters, known as hotspots and cold spots, respectively, using the ArcGIS optimized hotspot analyses tool. For the emerging hotspot analyses, we generated 530 space–time bins to incorporate the temporal aspect of trends. The optimized hotspot analysis involved considering neighboring values to yield clustered outputs of low and high DR values, categorizing them as cold spots and hotspots, respectively.

Conversely, the emerging hotspot analysis focused on changes within specific bins (representing a country's distinctive DR data) to present a more robust output based on trends or alterations. This latter analysis categorized locations as new, consecutive, intensifying, persistent, or other types of hot- or cold spots, offering a more nuanced understanding of the evolving DR landscape. For a more comprehensive technical analysis of how the optimized and emerging hotspot analyses in ArcGIS works, readers are encouraged to review Esri (2023a), (2023b) respectively.

II.1.4. Results

II.1.4.1. Patterns and trends of DR in Africa (2012 to 2022)

II.1.4.1.1. Continental, regional and country-level trends

From our analyses of the data, DR in Africa from 2012 to 2022 reveals intriguing trends and regional disparities (Figure II.1–2–a). Notably, there has been a slight overall increase in DR across the continent during this period. Regional disaggregation shows variations across the continent (Figure II.1–2–b). Among the regions, Northern Africa stands out as the exception, demonstrating a decline in DR since 2020. Conversely, Central, Eastern, Western, and Southern Africa have witnessed a steady rise in DR during the same timeframe. Furthermore, individual country-level analysis exposes a spectrum of trends in DR (Figure II.1–2–c).

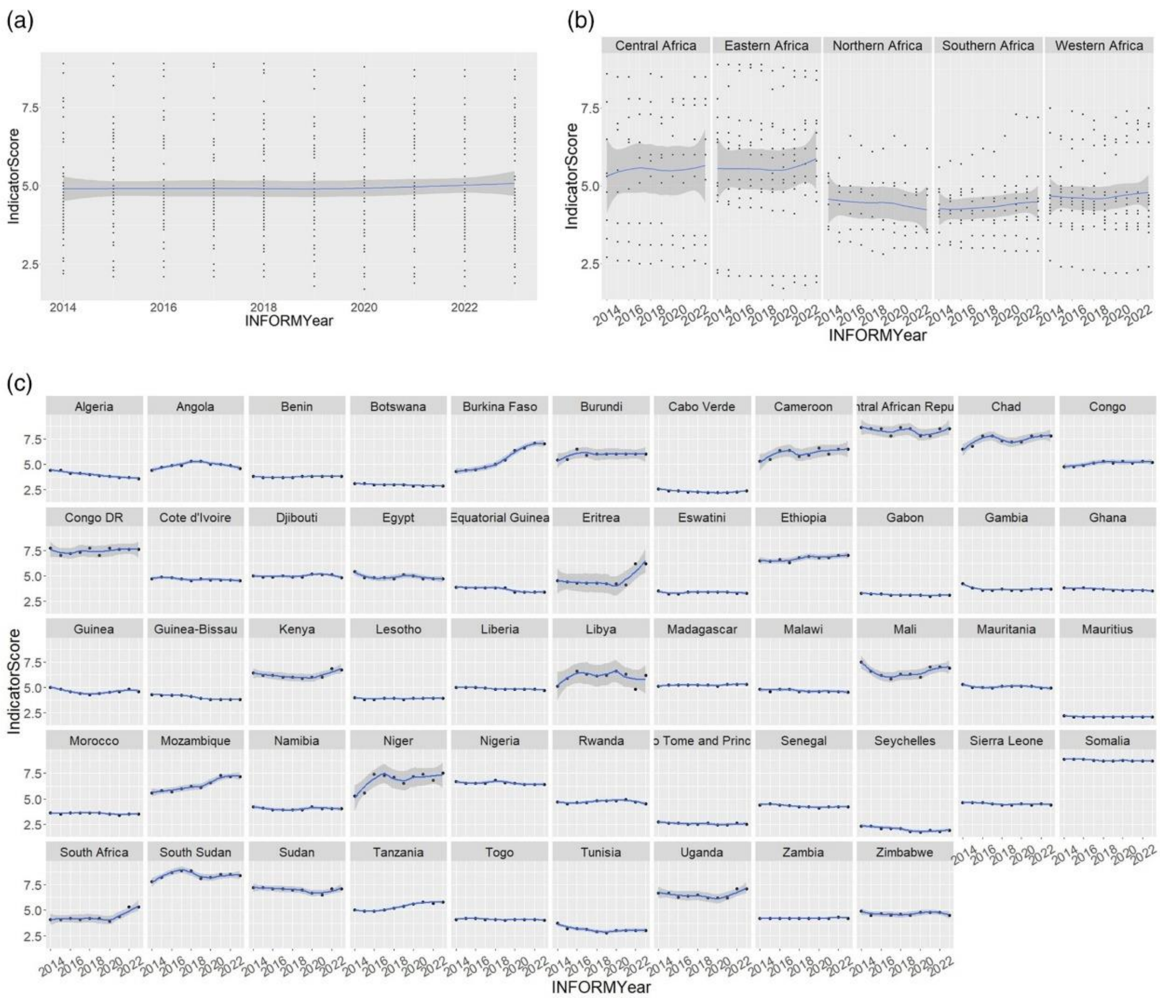

Figure II.1–2: Smoothened trend plots of INFORM risk index (2012–2022) (a) continental DR trend for Africa (b) regional–level trends (c) country–level trends.

Burkina Faso, Central African Republic, Uganda, and South Africa notably experienced a steep increase in DR in recent years. Meanwhile, countries like Cameroon, Chad, Ethiopia, Mali, Mozambique, Niger, South Sudan, Sudan, and Tanzania have seen a gradual but persistent rise in their DR. Within the study period, Algeria, Botswana, and Gabon have displayed a consistent reduction in DR trends, reflecting proactive measures or unique circumstances mitigating disaster occurrences. However, the situation in Libya stands in contrast, characterized by a volatile pattern in DR, showcasing intermittent declines in recent years.

II.1.4.1.2. Mann-Kendall analyses results

Surprisingly, the outcomes derived from the MK monotonic trend analyses present a contrast to the trends depicted visually in Figures 2a–c. The MK analysis suggests an overall decrease in DR for the entire African continent, which diverges from the visual representations. Again, the MK results shed light on the disparities within Africa's regions (Table II.1–2). They indicate a decreasing trend in DR for Central and Northern Africa, while showcasing an opposing trend of increasing DR in Eastern, Western, and Southern Africa. It's crucial to note that despite these observed trends, these findings are not statistically significant.

The non-significant trends revealed by the MK analyses across the regions imply caution in interpreting the directionality of the observed changes. While the visual representations in Figures II.1–2–a–c might suggest specific patterns, the statistical analysis portrays these trends as not meeting the threshold of significance. This incongruence between visual representations and statistical analyses prompts a deeper exploration into the reasons behind these disparities. It underscores the complexity of assessing trends in DR and emphasizes the need for multifaceted analyses, considering factors beyond mere visual observations. Recognizing the lack of statistical significance in the observed trends is crucial in preventing premature conclusions. Despite the apparent trends in different regions, the absence of significance calls for a cautious interpretation of these findings.

II.1.4.1.3. Trend results of category-level DR factors

The analysis of key components constituting African DR in the last decade exposes intriguing patterns (Figure II.1–3–a). Notably, human hazards and vulnerabilities among specific groups have seen an alarming rise, while there's been a slight reduction observed in the institutional and infrastructural coping capacities. Regional assessments further illuminate the disparities in these DR factors across Africa (Figure II.1–3–b). Central, Eastern, Southern, and Western Africa have experienced a significant and steep increase in human hazards, while a contrasting decline in this factor has been observed in Northern Africa.

Interestingly, all regions have shown a linear reduction in the lack of coping capacity, notably in the infrastructural component. However, three regions—East, North, and South—have witnessed an increase in vulnerable groups. Moreover, while Central Africa's socio-economic vulnerability component remained stagnant, the other four regions—East, West, North, and South—exhibited a reduction in this factor (Figure II.1–3–b). At the country level, specific trends in category-level DR factors are discernible (Figure II.1–3–c). Burkina Faso, Mozambique, Niger, South Africa, and Tanzania witnessed a steep increase in human hazards, whereas Algeria and Tunisia experienced a significant reduction in this factor.

The outcomes derived from the MK monotonic trend analyses present a unique narrative, diverging from the visual representations of trends (Figure II.1–3). Overall, these analyses highlight a declining trend in the lack of infrastructural coping capacity against an increasing deficit in institutional coping capacity. Notably, Central Africa's escalating lack of institutional coping capacity holds statistical significance, alongside the declining socio-economic vulnerability factor (Table II.1–2).

Table II.1–2: Mann-Kendall monotonic trend analyses results

Region	Risk Index	Natural Hazards	Human Hazards	Vulnerable Groups	Socio-Economic Vulnerability	Infrastructure	Institutional
Central Africa	–ve	–ve	–ve	–ve	–ve*	–ve	+ve*
Eastern Africa	+ve	–ve	+ve	+ve	+ve	–ve	+ve
Northern Africa	–ve	–ve	–ve	–ve	+ve	–ve	+ve
Southern Africa	+ve	+ve	+ve	+ve	+ve	–ve	+ve
Western Africa	+ve	+ve	+ve	+ve	+ve	–ve	+ve
ALL continent	–ve	–ve	–ve	+ve	+ve	–ve	+ve

Note:
+ve*= Positive trend (significant at $p < .05$); +ve = Positive trend (non-significant)
–ve* = Negative trend (significant at $p < .05$); –ve = Negative trend (non-significant)

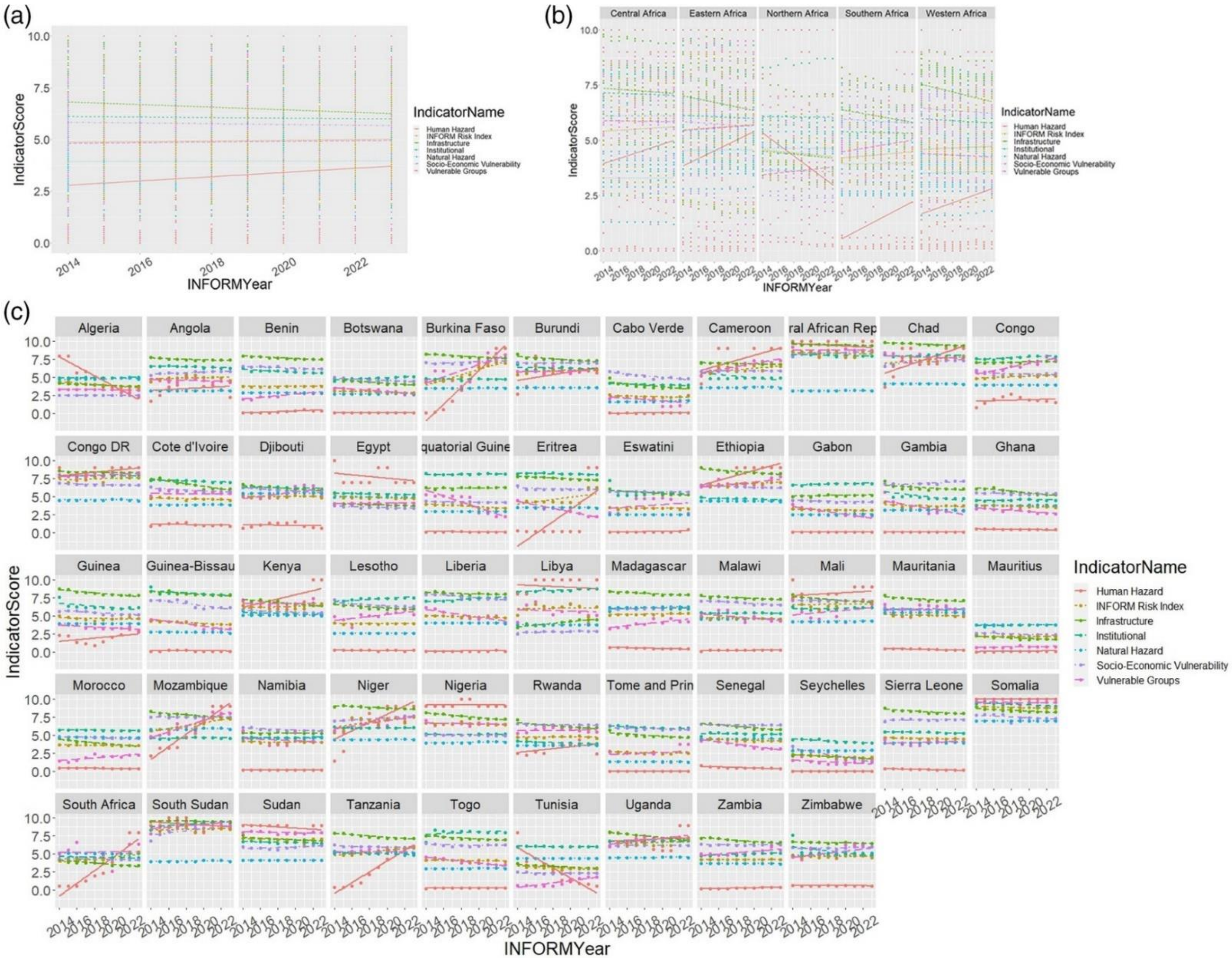

Figure II.1–3: Multi trend plots of category-level risk factors (a) continental–level (b) regional–levels (c) country–levels

II.1.4.2. Results of variable importance for DR factors in Africa

In this section, we provide the findings of our decadal and decadal mean assessment of significant factors impacting DR in Africa. Our Random Forest (RF) models constructed 500 trees for each assessment, with seven factors explored at each split. Remarkably, the RF regression algorithm effectively explained the dependent variables, accounting for 62.42% and 91.59% of variables in the decadal and decadal mean analyses, respectively. Seven key measures of importance as listed in the methods section were obtained from our analyses. Table 3 displays the frequency of occurrence among the top ten factors identified by each measure.

From our comprehensive decadal and decadal mean assessments involving 22 factors as independent variables, only ten are identified by the variable importance measures for up to a 50% frequency as significant DR factors. These factors include economic dependency, inequality, physical exposure to tropical cyclones and tsunamis, recent shocks, current conflicts, DRR, physical exposure to earthquakes, epidemics, and uprooted people (Table II.1–3). Additionally, health conditions, other vulnerable groups, people affected by droughts, and violent conflict probability, while slightly below 50%, warrant attention due to their significance (Table II.1–3).

Furthermore, the multi-way importance plots, another product of RF regression analyses, offer substantial insights into the factors of Africa's DR (Figure II.1–4a, c). These plots provide a machine-combined perspective, highlighting essential aspects such as the mean depth of initial splits on variables, the number of trees with root splits, and the total nodes splitting on specific variables, with notable factors highlighted in blue.

Table II.1–3: Top occurring significant factors of DR in Africa from seven variable importance measures.

Rank	Factor	Frequency[a]	Frequency[b]	Total frequency a+b	% of all occurrences[c]
1	Economic Dependency	5	5	10	71.43
2	Inequality	5	5	10	71.43
3	Physical exposure to tropical cyclones	4	5	9	64.29
4	Physical exposure to tsunamis	4	5	9	64.29
5	Recent shocks	5	4	9	64.29
6	Current conflicts	5	3	8	57.14
7	Disaster Risk Reduction	5	3	8	57.14
8	Physical exposure to earthquakes	3	5	8	57.14
9	Epidemic	2	5	7	50.00
10	Uprooted people	5	2	7	50.00
11	Health Conditions	2	4	6	42.86
12	Other Vulnerable Groups	4	2	6	42.86
13	People affected by droughts	2	4	6	42.86
14	Violent Conflict probability	4	2	6	42.86
15	Food Security	2	3	5	35.71
16	Access to Health Care	2	2	4	28.57
17	Communication	2	2	4	28.57
18	Governance	2	2	4	28.57
19	Physical Infrastructure	2	2	4	28.57
20	Poverty and Development	2	2	4	28.57
21	Health of children under five	2	1	3	21.43
22	Physical exposure to floods	1	2	3	21.43

Notes:

a = frequency of the factor's occurrence among the top ten importance measures in the random forest regression of decadal analyses of disaster risk

b = frequency of the factor's occurrence among the top ten importance measures in the random forest regression of decadal mean analyses of disaster risk

c = the percentage of the factor's occurrence of the total possible occurrences of both the decadal and decadal mean analyses of disaster risk

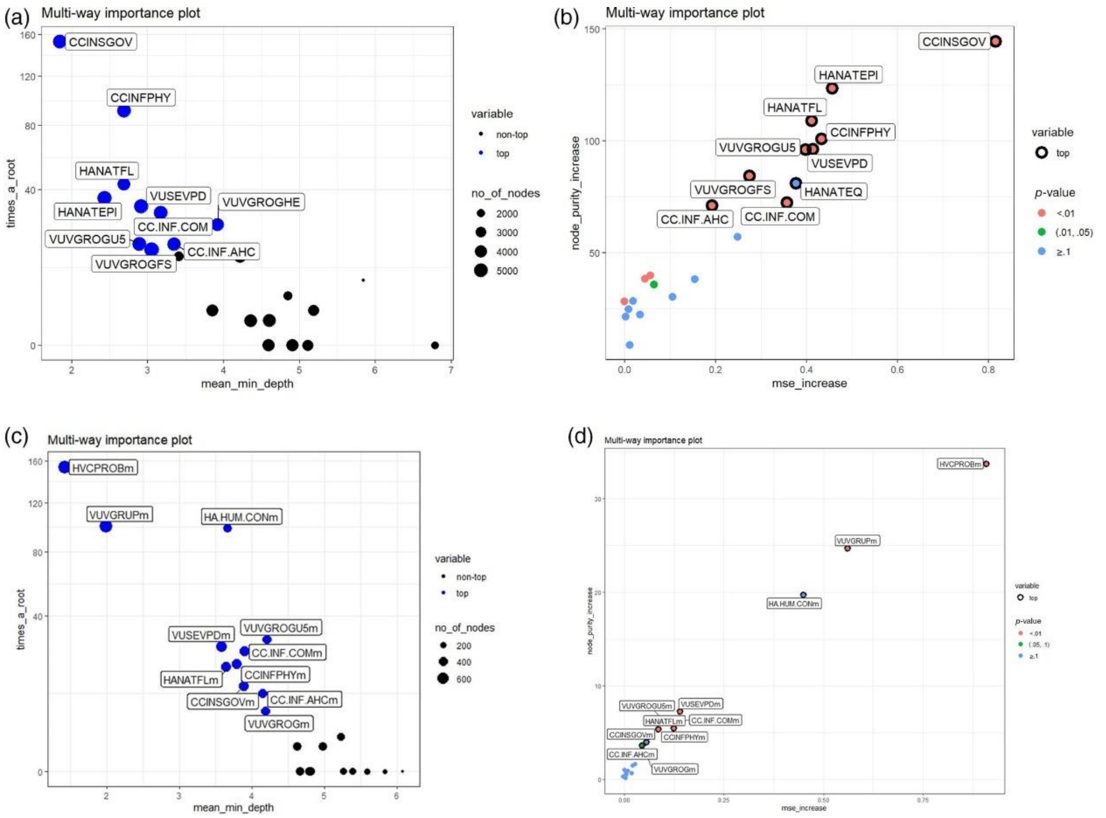

Figure II.1–4: Multi-way importance plots: (a, c)–classification of the top and non-top factors based on the minimum average depth, times to root and the number of nodes (b, d)–top factors based on MSE increase, node purity increase and p-value (pink circle = $p < 0.01$).

Machine-combined importance measures from the decadal analyses pinpoint significant drivers influencing Africa's DR. Notable among these drivers are epidemics, governance, physical infrastructure, poverty and development, physical exposure to floods, health of children under five, food security, communication, and access to healthcare (Figure II.1–4–b) (Table II.1–4). Similarly, the decadal mean analyses highlight impactful drivers like violent conflict probability, uprooted people, poverty and development, physical exposure to floods, physical infrastructure, communication, governance, health of children under five, and access to healthcare (Figure II.1–4–d) (Table II.1–4).

Table II.1–4: Top significant factors of Africa's disaster risk based on machine-coupled importance measures of decrease in accuracy, node purity increase, and *p*-value

Core factor	**Top significant component**
Hazard	
Natural hazard	Epidemics [d]
	Physical exposure to floods [d]
Human hazard	Projected conflict risk [m]
Vulnerability	
Socioeconomic vulnerability	Development and deprivation [d,m]
Vulnerable groups	Uprooted people [m]
	Health of children under five [d,m]
	Food security [d]
Lack of coping capacity	
Institutional	Governance [d,m]
Infrastructure	Physical infrastructure [d,m]
	Access to health care [d,m]
	Communication [d,m]

Notes:
d = Significant factors unique to decadal analyses
m = Significant factors unique to decadal analyses
d,m = Significant factors recurring in both decadal and decadal mean analyses

II.1.4.3. Results of DR and factors' SSH

II.1.4.3.1. Detected risks

Our analysis, delineated in Table II.1–5, meticulously maps the distribution of DR across different strata based on specific factors. Notably, higher DR are clustered within strata exhibiting higher values of specific category-level factors. Specifically, higher strata memberships were recorded in higher levels of human hazard, lack of infrastructural coping capacity, institutional coping capacity, natural hazards, socio-economic vulnerability, and vulnerable groups. Overall strata membership of DR levels based on these category-level data are designated in percentages as 12.4% (very low), 17.8% (low), 26.4% (medium), 25.6% (high), and 17.8% (very high).

Table II.1–5: Results of stratified detected risks

Core disaster risk factors	Regions	Very low (0)	Very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)
Human Hazard	Continental	1.5	2.86	3.14	3.43	4.55	5
	Central	2	2.5	4	4	4.67	5
	Eastern	1	3	3.33	3	4.75	5
	Northern	*	3.5	2	3	3.5	*
	Southern	*	2.71	*	3.33	*	*
	Western	*	2.89	3	4	5	5
Infrastructure	Continental	*	1.5	2	2.7	3.39	4.05
	Central	*	*	*	2	3.67	4.75
	Eastern	*	1.5	*	*	3.75	4.43
	Northern	*	*	2	3.25	4	*
	Southern	*	*		2.67	2.75	3.33
	Western	*	*	2	3.33	3.63	
Institutional	Continental	*	*	2.91	3.42	3.33	4.09
	Central	*	*		3	3	4.4
	Eastern	*	*	2.75	4	4.25	4.33
	Northern	*	*	*	3.25	2	4
	Southern	*	*	3	2.75	3	*
	Western	*	*	3	3.86	3	3
Natural Hazard	Continental	*	2	2.33	3.6	3.64	*
	Central	*	2	2	4.29		*
	Eastern	*	*	*	3.63	4	*
	Northern	*	*	*	3	3.33	*
	Southern	*	*	2.33	3	3.33	*
	Western	*	*	2.5	3.54		*
Socio-Economic Vulnerability	Continental	*	*	2.5	2.89	3.56	4.5
	Central	*	*		2.5	4	5
	Eastern	*	*	1.5		4	5
	Northern	*	*	3	3	4	*
	Southern	*	*	*	2.5	2.86	4
	Western	*	*	*	3.25	3.33	4
Vulnerable Groups	Continental	*	1.67	2.4	2.94	3.44	4.72
	Central	*	*	2	3	4	4.6
	Eastern	*	1.5	*	3.5	3.33	4.83
	Northern	*	2	3	3	4	*
	Southern	*	*	*	2.33	3	4
	Western	*	*	2.5	3	3.75	5

*=No strata membership

II.1.4.3.2. Risk factors

Our exploration further delves into the significance of DR factors, elucidating their contribution to spatial stratified heterogeneity. As detailed in Table 6, three pivotal factors stand out significantly – vulnerable groups, human hazard, and lack of infrastructural coping capacity, respectively explaining 75%, 70%, and 42%, of DR in Africa. Distinct influential factors are spotlighted across various African regions. For instance, vulnerable groups emerge as a compelling explanatory factor, significantly driving DR in Central, Eastern, and Northern Africa, explaining between 88% to 100% of DR in the region. Conversely, human hazard significantly explains DR in Eastern and Western Africa, accounting for 83% and 92%, respectively. Notably, natural hazard factors predominantly explain DR in Central Africa over the last decade (90%).

Table II.1–6: Results of SSH q-statistics and factor significance

Regions	Human Hazard	Infrast ructure	Institu tional	Natural Hazard	Socio-Economic Vulnerability	Vulnerable Groups
Central	0.90	0.88**	0.38	0.70*	0.44	0.90*
Eastern	0.83*	0.66**	0.30	0.02	0.68	0.88***
Northern	0.65	0.74	0.74	0.05	0.29	1***
Southern	0.28	0.28	0.05	0.53	0.53	0.77
Western	0.92*	0.21	0.23	0.16	0.07	0.72
Continental	0.70***	0.42***	0.14	0.20	0.28	0.75***

Significance of q: *** above 0.001 level, ** at 0.01 level, * at 0.05 level.

II.1.4.3.3. Risk factor interactions

The examination of category-level factors interactions reveals compelling dynamics shaping DR. Our results, depicted in Table II.1–7, primarily showcase a bi-enhanced interaction among these factors. This signifies that their combined effect on DR surpasses the mere sum of their individual influences. However, a noteworthy exception emerges in the interaction between lack of institutional coping capacity and socio-economic vulnerability, indicating a non-linear enhancement (Table II.1–7). This suggests a complex relationship between these factors, implying that despite their individual influence on DR, their interaction operates beyond a linear trajectory.

Table II.1–7: Interaction results of core factors of disaster risk

Interacting factors	Regions				
	Central	Eastern	Southern	Western	Continental
Human Hazard ∩ Infrastructure	1	0.95	0.46	1	0.86
Human Hazard ∩ Institutional	1	1	0.46	0.96	0.80
Human Hazard ∩ Natural Hazard	0.95	0.98e-n	0.64	0.96	0.84
Human Hazard ∩ Socio-Economic Vulnerability	0.91	0.94	0.74	0.96	0.85
Human Hazard ∩ Vulnerable Groups	0.95	0.94	0.79	0.96	0.85
Infrastructure ∩ Institutional	0.96	0.74	0.59e-n	0.46	0.52
Infrastructure ∩ Natural Hazard	0.89	0.70	0.84	0.30	0.55
Infrastructure ∩ Socio-Economic Vulnerability	0.95	0.73	0.61	0.36	0.50
Infrastructure ∩ Vulnerable Groups	1	0.93	0.84	0.80	0.80
Institutional ∩ Natural Hazard	0.75	0.49e-n	0.84e-n	0.41	0.35
Institutional ∩ Socio-Economic Vulnerability	0.79	0.76	0.61	0.70e-n	0.54e-n
Institutional ∩ Vulnerable Groups	0.94	0.98	0.84	1	0.82
Natural Hazard ∩ Socio-Economic Vulnerability	0.91	0.73	0.84	0.31	0.45
Natural Hazard ∩ Vulnerable Groups	0.91	0.93	1	0.78	0.82
Socio-Economic Vulnerability ∩ Vulnerable Groups	0.92	0.89	0.84	0.84	0.78

Notes:

The model returned no results for the computation of factors' interaction effects for Northern Africa.

e-n = factors have an 'enhance, non-linear' interaction, all others are bi-enhance interaction

The interaction dynamics among DR factors shed light on factors shaping the continent's DR profile. Notably, the interplay between human hazard and lack of infrastructural coping capacity emerges as the most potent, influencing DR significantly at 86%. Conversely, the combined effects of lack of institutional capacity and natural hazards exhibit a comparatively weaker influence, accounting for 35% of DR (Table II.1–7). Apparently human hazards and other factors' combinations wield more substantial impacts on DR, necessitating focused attention in risk mitigation strategies.

The region-based results uncover intriguing regional differences in factor interactions, particularly in Central, Eastern, and Western Africa. These regions notably exhibit very high to perfect interaction effects ranging from 91% to 100% among category-level DR factors. Specifically, the interactions involving human hazard and lack of infrastructural coping capacity, institutional coping capacity, natural hazards, socioeconomic vulnerability, and vulnerable groups are notably robust (Table II.1–7). These interactions in Central Africa portray exceptionally high influences, ranging from 75% to 100%. However, it's important to note that the model couldn't be computed for Northern Africa, potentially signifying distinctive complexities or limitations in data availability for this region.

II.1.4.4. Disaster risk hotspot results

II.1.4.4.1. Disaster risk index of African countries

From the comprehensive decadal mean analyses, we observed a distinct categorization of African countries based on their DR indexes (Figure II.1–5a). Strikingly, 11 countries demonstrated very high DR, while an additional 10 countries showcased high-risk profiles. The middle ground was occupied by 24 countries exhibiting medium DR indexes. Surprisingly, only eight countries, predominantly island states such as Botswana, Cabo Verde, Eswatini, Gabon, Mauritius, Sao Tome and Principe, Seychelles, and Tunisia, displayed very low DR.

II.1.4.4.2. Optimized hotspot results

Showcasing the consistency of DR patterns, our optimized hotspot analysis revealed intriguing insights (Figure 5b). Highlights the clustering effect, where hotspots represent regions with concentrated high DR values, and cold spots indicate areas of comparatively lower DR, our results show 23 countries as cold spots, showcasing statistically significant lower DR values over the period 2012 to 2022 (i.e., Angola, Benin, Botswana, Burkina Faso, Cape Verde, Cote d'Ivoire, Ghana, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Senegal, Seychelles, Sierra Leone, South Africa, and Swaziland).

Conversely, 19 countries manifested as hotspots, signifying statistically significant higher DR values for the period (i.e., Burundi, Cameroon, Central African Republic, Chad, Congo, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Kenya, Libya, Malawi, Niger, Nigeria, Sudan, Uganda, and United Republic of Tanzania). Interestingly, six countries displayed non-significant results, not fitting into either hotspot or cold spot categories.

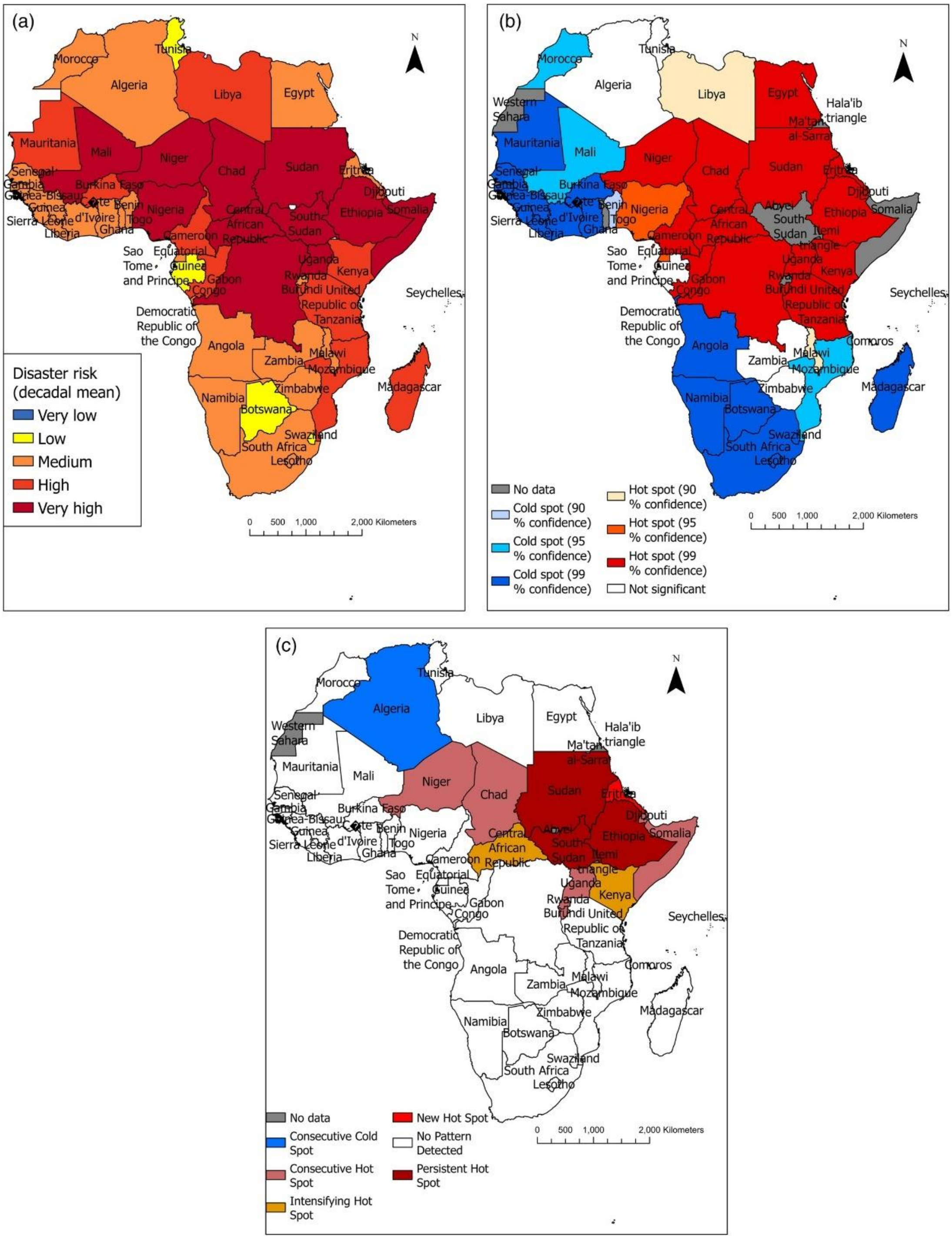

Figure II.1–5: Map of African countries showing: (a) DR classes based on decadal mean analyses of INFORM risk index (b) optimized Hotspots analyses results (c) emerging hotspots of DR s.

II.1.4.4.3. Emerging hotspot results

Unveiling emerging trends in DR during the period 2012 to 2022, the emerging hotspot analysis shed light on noteworthy changes in the period (Figure II.1–5c). Remarkably, Algeria emerged as a consecutive cold spot, indicating consistent lower DR levels, while Eritrea surfaced as a new hotspot, showcasing a recent significant rise in DR. Additionally, seven countries, including Burundi, Chad, Djibouti, Niger, Rwanda, Somalia, and Uganda, exhibited a consecutive hotspot trend, experiencing a surge in DR over the later period covered by the analyses.

Amidst these analyses, specific countries showcased distinctive patterns in DR intensification or persistence. Central African Republic and Kenya emerged as intensifying hotspots, with a consistent increase in DR intensity over time. Conversely, Ethiopia, South Sudan, and Sudan appeared as persistent hotspots, maintaining consistently high DR indexes over the studied period. No discernible pattern was detected in 37 other countries, as they did not align with either the identified hotspots or cold spots derived from the analyses.

II.1.5. Discussion

II.1.5.1. Disaster risk trends and hotspots in Africa

During the study period, Africa experienced a slight overall increase in DR, but the MK analysis revealed statistically non-significant declining trends. Smoothened plots and MK outcomes highlighted escalating DR in Eastern, Western, and Southern Africa. Specific countries—such as Cameroon, Chad, Ethiopia, Mali, Mozambique, Niger, South Sudan, Sudan, and United Republic of Tanzania—consistently observed rising DR trends.

While six of these countries (i.e., Cameroon, Chad, Ethiopia, Niger, Sudan, and United Republic of Tanzania) are also identified as DR hotspots in Africa, other hotspot countries such as Burundi, Central African Republic, Congo, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Kenya, Libya, Malawi, Nigeria, and Uganda were not detected by the initial smoothened plots. This reveals a potential limitation in the efficacy of such methods in visualizing trends accurately. Notably, infrastructural deficiencies displayed a consistent decreasing trend across all African regions, in contrast to the escalating lack of institutional coping capacity.

The findings from our study reveal a combination of anticipated and surprising outcomes. The observed slight overall increase in DR across Africa appears consistent with the global trend of escalating disaster occurrences, as reported by Mizutori and Guha-Sapir (2020), who noted a sharp rise in both the frequency and severity of global disaster events. This aligns with prior studies emphasizing the increase of various dimensions of DR, encompassing hazards and vulnerability, as reported by Aliyu (2015). Specifically, research by Bari and Dessus (2022) underscores the detrimental impact of floods and droughts in Africa, causing up to a 0.7% decline in GDP, indicative of increased poverty resulting from hazardous events.

The identification of statistically non-significant declining trends through the MK analysis introduces complexities in drawing definitive conclusions. Also, comparing our trend results with previous works is challenging due to limited available data. Nevertheless, assessments like Ahmadalipour and Moradkhani's (2018) drought vulnerability assessment highlighted Chad and Niger as highly vulnerable countries in Africa, correlating with our findings of increasing DR in these regions and their designation as hotspots.

Similarly, Li et al.'s (2016) Africa-wide flood disaster assessment identified Ethiopia, Sudan, and United Republic of Tanzania as among the most affected countries, consistent with our identification of these nations as experiencing rising DR and as hotspots. The varying levels and trends of DR identified in our study align with the risk distribution dimension expounded by Imperiale and Vanclay (2021). The variability observed in DR levels and hotspots across different regions and the fluctuating trends over time resonate with the concept of risk distribution as an essential component in understanding the spatial and temporal dynamics of risks.

The declining trend in infrastructural coping capacity might signify improvements in infrastructure development, potentially attributed to increased investments or initiatives targeting infrastructure resilience, possibly influenced by global frameworks like the UN's Agenda 2030 and SFDRR. These initiatives could be translating into specific improvements in physical infrastructures and access to healthcare, as captured in the INFORM model. Conversely, the escalating lack of institutional coping capacity could mirror challenges in governance, resource allocation, corruption, or the efficacy of disaster management policies. However, our study lacks additional data to delve deeper into the specific reasons for these trends beyond the indicators within the INFORM model.

Additionally, it's important to note that the data analyzed in this paper pertains to 2012 to 2022, a period preceding recent disasters occurring between April and September 2023. These disasters, stemming from natural hazards such as the floods in Libya, DR Congo, and Rwanda, the earthquake in Morocco, wildfires in Algeria, and the cyclone in Mozambique, are not accounted for in our analysis. These recent events might have influenced the evolving landscape of DR in Africa, potentially altering the trends and dynamics observed in our study. Their omission underscores a limitation in our analysis, indicating the need for further assessment and updated data to comprehensively capture the contemporary scenario of DR in the region.

II.1.5.2. Disaster risk drivers in Africa

Our findings pinpointed key drivers of DR, including epidemics, flood exposure, projected conflict risk, development indicators, displacement, child health, food security, governance, infrastructure, healthcare access, and communication. Approximately 43% of the countries assessed fell within high and very high clusters of DR levels. Our continental-wide findings revealed that vulnerable groups and human-induced hazards collectively accounted for more than 70% of the explanation for the DR index. Evidently, the interaction between human-induced hazards and factors in other categories exerted the most significant influence on DR across the continent.

The interaction between human-induced hazards, encompassing current highly violent conflicts and projected conflict risks, emerged as the primary amplifier of DR across the African continent. This concurs with projections made by Corral et al. (2020), highlighting a grim outlook should violent conflicts persist in the region. Notably, violent conflicts not only impede sustainable development but also exacerbate DR by escalating displacement, adversely impacting vulnerable groups, and intensifying food insecurity, as illuminated by Anderson et al. (2021).

Among the 11 key DR drivers in Africa identified in our study, only two are associated with hazards, while the rest pertain to vulnerability and lack of coping capacity dimensions. This aligns with Bailey's (2022) conceptualization of disasters as comprising hazards and the social system. These dimensions encompass weaknesses capable of exacerbating social risks and affecting the wellbeing of countries, as echoed by Samaraweera (2023) and Imperiale & Vanclay (2021). Encouragingly, the influence of natural hazards on DR in Africa seems lower, providing an opportunity for addressing controllable social drivers emphasized by Ginige (2011).

Our findings bridge a gap highlighted by Drakes and Tate (2022), addressing the scarcity of large-scale research into social vulnerabilities in lower-income nations. The identified social vulnerability drivers could guide interventions aimed at reversing these trends. Failure to mitigate vulnerability may lead to increased future disaster losses, potentially perpetuating the poverty cycle, as suggested by Hallegatte et al. (2020) and Salvucci & Santos (2020). This emphasizes the interconnectedness of poverty reduction, equitable resource distribution, DRR, and sustainable development advocated by Naheed (2021), as well as the impact of poverty on impeding development and the success of SDGs, as emphasized by Akanle et al. (2022).

Furthermore, our findings provide insights into the long-term causes and consequences of vulnerability, aligning with Kelman et al. (2015) assertion that such insights are crucial for developing diverse intervention strategies to build resilience. Information-driven policies, as highlighted by Chen et al. (2021), are imperative for DRR and sustainable development. Governance, identified as a DR driver, underscores the necessity for capacity building to enhance the effectiveness of human resources (Acharibasam & Datta, 2023), addressing concerns raised by Becker and van Niekerk (2015), Bang (2014, 2022), about the deficiency of skilled DRR practitioners in Africa, which leads to delay in the translation of policies into actions.

Lastly, the identified DR drivers emphasize the need, as advocated by Imperiale and Vanclay (2016, 2021), for deliberate efforts to reduce vulnerability while simultaneously increasing resilience. Addressing vulnerability drivers such as child health does not inherently provide healthcare access, a coping capacity driver of DR, highlighting the importance of a multifaceted approach. However, it's essential to note that the coarse national-level data used in this study might not capture community-level variations in vulnerabilities and coping capacities.

Therefore, community-level studies across African states and regions are crucial to fully optimize the potential of such studies, enabling the most effective DRR approaches, as advocated by Jafari et al. (2018) and Zhou et al. (2015), and the implementation of robust DRR governance, as highlighted by Jiménez-Aceituno et al. (2020).

II.1.6. Conclusion

In examining DR trends, drivers and hotspots in Africa, our study unveiled various outcomes. The results from our MK trend tests indicate an overall decrease in DR across the continent over the studied period, albeit with regional variations. Specifically, the patterns of DR in Central and Northern Africa align with the continental trend, showing a decline. In contrast, Eastern, Western, and Southern Africa exhibit increasing trends in DR during the same period. Notably, Eritrea emerged as a new hotspot. While Burundi, Chad, Djibouti, Niger, Rwanda, Somalia, and Uganda, are consecutive hotspot trends; Central African Republic and Kenya intensified in DR, and Ethiopia, South Sudan, and Sudan remained persistent hotspots.

These findings indicate the evolving nature of DR and highlight specific countries required more focus and tailored interventions. Additionally, our identification of vulnerability and lack of coping capacity dimensions as predominant drivers of DR corroborates existing research. However, the intricate interplay between human-induced hazards related to violent conflicts and all other vulnerability and coping capacity factors form part of our primary contribution to understanding DR in Africa and warrants the consideration for multifaceted DRR strategies. Moreover, while recognizing the commendable declining trend in infrastructural deficiencies, persistent vulnerabilities and inadequate institutional coping capacity emphasize the imperative for sustained policy interventions.

Targeted strategies should be focused on simultaneously addressing these persisting vulnerabilities and building resilience. Strategies such as poverty reduction approaches, effective community-level bottom-up DRR governance and increased investments in capacity building initiatives are pivotal for mitigating risks and achieving sustainable development. Future community-level studies to complement our national-level analyses are required to enable more tailored and effective DRR strategies. Moreover, findings such as the conflicting outcomes of the smoothened plots and the MK trend tests can be easily avoided. Also, contextual policy actions can be founded on such community-level research. Furthermore, DR assessments ought to be ongoing and updated to ensure evolving and recent risk scenarios are adequately captured.

We, therefore, present a compelling call for coordinated efforts with local communities, policies, actions, and further research to address the multifaceted nature of DR in Africa to fortify resilience, and reduce vulnerabilities to achieve sustainable development in the continent.

II.1.7. Limitations of the study

The study's design was significantly influenced by the limited availability of long-term data on DR dynamics in Africa. Despite the preference for designing community-level DR assessments, the absence of prior empirical assessments at lower scales constrained the scope of this study. Likewise, the scarcity of local studies on DR limits the validation of findings on lower-level scales. To address this, we strongly advocate for in-depth case studies on specific hazard-induced disasters that provide deeper insights into DR at local scales in Africa. Such studies could supplement our findings by offering context-specific knowledge on social dimensions of risks and resilience, like the insights provided by Imperiale and Vanclay (2016, 2021), Samaraweera (2023), Fransen et al (2023) and other local research captured in this work.

Furthermore, our study utilized the INFORM index data, acknowledging the providers' identification of methodological and data limitations (Marin-Ferrer et al., 2017). Methodologically, the use of proxies, such as malaria mortality rates for malaria prevalence, might limit the representativeness of the findings. Additionally, incomplete data, reliance on self-measured Hyogo self-assessment reports from countries, and the static nature of natural hazard data necessitate caution in interpreting the results. It's crucial to recognize these limitations and their potential impact on the study's conclusions.

Moreover, our study excludes the recent hazardous events in Africa within 2023, which emphasizes the necessity for ongoing and updated DR assessments to capture the ever-evolving landscape of DR in the continent. Also, while our smoothened trend plots offer insights into DR trends, contrasting outcomes yielded by the MK results warrant careful interpretation. The divergence in results signifies the complexity of trend analyses and underscores the need for cautious interpretation of the study's findings. Despite these limitations, our study offers a distinctive panoramic view of DR trends, influential factors, and hotspots across Africa. By uncovering these insights, our research presents actionable opportunities for DRR strategies and sustainable development initiatives.

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II.1.9. References

Abdel Hamid, H. T., Wenlong, W., & Qiaomin, L. (2020). Environmental sensitivity of flash flood hazard using geospatial techniques. *Global Journal of Environmental Science and Management*, 6(1), 31-46. https://doi.org/10.22034/GJESM.2020.01.03

Acharibasam, J. B., & Datta, R. (2023). Enhancing community resilience to climate change disasters: Learning experience within and from sub-Saharan black immigrant communities in western Canada. *Sustainable Development*. https://doi.org/10.1002/sd.2677

Adaawen, S., Rademacher-Schulz, C., Schraven, B., & Segadlo, N. (2019). Drought, migration, and conflict in sub-Saharan Africa: what are the links and policy options? *Current Directions in Water Scarcity Research*, 2, 15-31. https://doi.org/10.1016/B978-0-12-814820-4.00002-X

Africa Center for Strategic Studies (2022). Cyclones and More Frequent Storms Threaten Africa https://africacenter.org/spotlight/cyclones-more-frequent-storms-threaten-africa/#:~:text=As%20oceans%20have%20warmed%2C%20Africa,runs%20from%20November%20through%20March.

Ahmadalipour, A., & Moradkhani, H. (2018). Multi-dimensional assessment of drought vulnerability in Africa: 1960–2100. *Science of the total environment*, 644, 520-535. https://doi.org/10.1016/j.scitotenv.2018.07.023

Aka, F. T., Buh, G. W., Fantong, W. Y., Zouh, I. T., Djomou, S. L. B., Ghogomu, R. T., ... & Hell, J. V. (2017). Disaster prevention, disaster preparedness and local community resilience within the context of disaster risk management in Cameroon. *Natural hazards*, 86, 57-88. https://doi.org/10.1007/s11069-016-2674-5

Akanle, O., Kayode, D., & Abolade, I. (2022). Sustainable development goals (SDGs) and remittances in Africa. *Cogent Social Sciences*, 8(1), 2037811. https://doi.org/10.1080/23311886.2022.2037811

Aliyu, A. (2015). Management of disasters and complex emergencies in Africa: The challenges and constraints. *Annals of African Medicine*, 14(3), 123. DOI: 10.4103/1596-3519.149894

AlQahtany, A. M., & Abubakar, I. R. (2020). Public perception and attitudes to disaster risks in a coastal metropolis of Saudi Arabia. *International journal of disaster risk reduction*, 44, 101422. https://doi.org/10.1016/j.ijdrr.2019.101422

Anderson, W., Taylor, C., McDermid, S., Ilboudo-Nébié, E., Seager, R., Schlenker, W., ... & Markey, K. (2021). Violent conflict exacerbated drought-related food insecurity between 2009 and 2019 in sub-Saharan Africa. *Nature Food*, 2(8), 603-615. https://doi.org/10.1038/s43016-021-00327-4

Bailey, E. (2022). Disaster Risk Reduction and Management: Recalling the Need for Paradigm Shift in Definition. *Journal of Geoscience and Environment Protection*, 10(6), 86-105. https://doi.org/10.4236/gep.2022.106006

Bang, H. N. (2014). General overview of the disaster management framework in Cameroon. *Disasters*, 38(3), 562-586. https://doi.org/10.1111/disa.12061

Bang, H. N. (2022). A Concise Appraisal of Cameroon's Hazard Risk Profile: Multi-Hazard Inventories, Causes, Consequences and Implications for Disaster Management. *GeoHazards*, 3(1), 55-87. https://doi.org/10.3390/geohazards3010004

Bari, M., & Dessus, S. (2022). *Adapting to Natural Disasters in Africa*. https://www.ifc.org/wps/wcm/connect/775d1c2f-a9f3-4b7d-b0d7-72738b42e3b8/Working-Paper-Adapting-to-Natural-Disasters-in-Africa.pdf?MOD=AJPERES&CVID=ohpHufW

Beccari B. (2016). A Comparative Analysis of Disaster Risk, Vulnerability and Resilience Composite Indicators. *PLoS currents*, 8. https://doi.org/10.1371/currents.dis.453df025e34b682e9737f95070f9b970

Becker, P., & van Niekerk, D. (2015). Developing Sustainable Capacity for Disaster Risk Reduction in Southern Africa. In *Hazards, Risks, and Disasters in Society* (pp. 63-78). Academic Press. https://doi.org/10.1016/B978-0-12-396451-9.00005-6

Bello, O., Bustamante, A., & Pizarro, P. (2021). *Planning for disaster risk reduction within the framework of the 2030 Agenda for Sustainable Development*. Project Documents (LC/TS.2020/108), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC). https://repositorio.cepal.org/server/api/core/bitstreams/ae6fe59f-e288-431b-8edd-7cbe1f760c8d/content

Bendimerad, F. (2003, April). *Disaster risk reduction and sustainable development*. In *World Bank Seminar on The Role of Local Governments in Reducing the Risk of Disasters*, Held in Istanbul, Turkey, 28, 57-75. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=721929932392f6b5d9bd4861f615d8554dade5e1

Birkmann, J., & Wisner, B. (2006). Measuring the un-measurable: The challenge of vulnerability, *Studies of the University research counsel education publication series*, Bonn. https://d-nb.info/1029694141/34

Birkmann, J., Hettige, S., & Fernando, N. (2006). Measuring vulnerability in Sri Lanka at the local level. In J. Birkmann (Ed.), *Measuring vulnerability to natural hazards: Towards disaster resilient societies* (pp. 329–356). United Nations University Press.

Birkmann, J., Jamshed, A., McMillan, J. M., Feldmeyer, D., Totin, E., Solecki, W., ... & Alegría, A. (2022). Understanding human vulnerability to climate change: A global perspective on index validation for adaptation planning. *Science of The Total Environment*, 803, 150065. https://doi.org/10.1016/j.scitotenv.2021.150065

Bornhofen, E., Ramires, T. G., Bergonci, T., Nakamura, L. R., & Righetto, A. J. (2019). Associations between global indices of risk management and agricultural development. *Agricultural Systems*, 173, 281-288. https://doi.org/10.1016/j.agsy.2019.03.006

Cardona, O.D., M.K. van Aalst, J. Birkmann, M. Fordham, G. McGregor, R. Perez, R.S. Pulwarty, E.L.F. Schipper, & B.T. Sinh (2012): Determinants of risk: exposure and vulnerability. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, 65-108. https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap2_FINAL-1.pdf

Caso, N., Hilhorst, D., Mena, R., & Papyrakis, E. (2023). Does disaster contribute to armed conflict? A quantitative analysis of disaster–conflict co-occurrence between 1990 and 2017. *International Journal of Development Issues.* https://doi.org/10.1108/IJDI-01-2023-0015

Chen, F., Shirazi, Z., & Wang, L. (2021). Building scientific capacity in disaster risk reduction for sustainable development. *Cultures of Science*, 4(1), 40-54. https://doi.org/10.1177/20966083211017330

Chipangura, P., Van Niekerk, D., & Van Der Waldt, G. (2017). Disaster risk problem framing: Insights from societal perceptions in Zimbabwe. *International journal of disaster risk reduction*, 22, 317-324. https://doi.org/10.1016/j.ijdrr.2017.02.012

Corral, P., Irwin, A., Krishnan, N., Mahler, D.G. and Vishwanath, T. (2020). *Fragility and conflict: on the front lines of the fight against poverty.* No. 146627, World Bank,1-116. doi:10.1596/978-1-4648-1540-9

Drakes, O., & Tate, E. (2022). Social vulnerability in a multi-hazard context: a systematic review. *Environmental research letters*, 17(3), 033001. https://doi.org/10.1088/1748-9326/ac5140

Egawa, S., Jibiki, Y., Sasaki, D., Ono, Y., Nakamura, Y., Suda, T., & Sasaki, H. (2018). The correlation between life expectancy and disaster risk. *Journal of Disaster Research*, 13(6), 1049-1061. https://doi.org/10.20965/jdr.2018.p1049

Esri. (2023a). *How Optimized Hot Spot Analysis works.* https://pro.arcgis.com/en/pro-app/3.0/tool-reference/spatial-statistics/how-optimized-hot-spot-analysis-works.htm

Esri. (2023b). *How emerging hot spot analysis works.* https://pro.arcgis.com/en/pro-app/3.0/tool-reference/space-time-pattern-mining/learnmoreemerging.htm

Fransen, J., Hati, B., Simon, H. K., &van Stapele, N. (2023). Adaptive governance by communitybased organisations: Community resilience initiatives duringCovid-19 in Mathare, Nairobi. *Sustainable Development*,1–12. https://doi.org/10.1002/sd.2682

Garschagen, M., Doshi, D., Reith, J., & Hagenlocher, M. (2021). Global patterns of disaster and climate risk—an analysis of the consistency of leading index-based assessments and their results. *Climatic Change*, 169(1-2), 11. https://doi.org/10.1007/s10584-021-03209-7

Getis, A., & Ord, J. K. (1992). The analysis of spatial association by use of distance statistics. *Geographical analysis*, 24(3), 189-206. https://doi.org/10.1111/j.1538-4632.1992.tb00261.x

Ginige, K. (2011). 16 Disaster Risk Reduction and its Relationship with Sustainable Development. *Post-Disaster Reconstruction of the Built Environment*, 287. https://doi.org/10.1002/9781444344943.ch16

Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Bangalore, M., & Beaudet, C. (2020). From poverty to disaster and back: A review of the literature. *Economics of Disasters and Climate Change*, 4, 223-247. https://doi.org/10.1007/s41885-020-00060-5

Imperiale, A. J., & Vanclay, F. (2016). Experiencing local community resilience in action: Learning from post-disaster communities. *Journal of Rural Studies*, 47, 204–219. https://doi.org/10.1016/j.jrurstud.2016.08.002

Imperiale, A. J., & Vanclay, F. (2021). Conceptualizing community resilience and the social dimensions of risk to overcome barriers to disaster risk reduction and sustainable development. *Sustainable Development*, 29(5), 891-905. https://doi.org/10.1002/sd.2182

Imperiale, A. J., & Vanclay, F. (2023). Re-designing Social Impact Assessment to enhance community resilience for Disaster Risk Reduction, Climate Action and Sustainable Development. *Sustainable Development.* https://doi.org/10.1002/sd.2690

Ismail-Zadeh, A. (2022). Natural hazards and climate change are not drivers of disasters. *Natural Hazards* 111, 2147–2154. https://doi.org/10.1007/s11069-021-05100-1

Jafari, A. J., Baba, M., & Dowlati, M. (2018). Disaster risk assessment in health centers of Iran University of Medical Sciences in functional, non structural & structural components during 2015-2016. *Iran Occupational Health*, 15(1), 76-85.

Jiménez-Aceituno, A., Peterson, G. D., Norström, A. V., Wong, G. Y., & Downing, A. S. (2020). Local lens for SDG implementation: lessons from bottom-up approaches in Africa. *Sustainability Science*, 15, 729-743. https://doi.org/10.1007/s11625-019-00746-0

Joint Research Centre [JRC] (2023). *INFORM Methodology*. Disaster Risk Management Knowledge Centre: European Commission. Accessed December 8, 2023

Kapucu, N., Hawkins, C. V., & Rivera, F. I. (2013). Disaster preparedness and resilience for rural communities. *Risk, Hazards & Crisis in Public Policy*, 4(4), 215-233. https://doi.org/10.1002/rhc3.12043

Keating, A., Campbell, K., Mechler, R., Magnuszewski, P., Mochizuki, J., Liu, W., ... & McQuistan, C. (2017). Disaster resilience: what it is and how it can engender a meaningful change in development policy. *Development Policy Review*, 35(1), 65-91. https://doi.org/10.1111/dpr.12201

Kelman, I. (2015). Climate change and the Sendai framework for disaster risk reduction. *International Journal of Disaster Risk Science*, 6, 117-127. https://doi.org/10.1007/s13753-015-0046-5

Kelman, I., Gaillard, J. C., & Mercer, J. (2015). Climate change's role in disaster risk reduction's future: Beyond vulnerability and resilience. *International Journal of Disaster Risk Science*, 6, 21-27. https://doi.org/10.1007/s13753-015-0038-5

Kelman, I., Gaillard, J. C., Lewis, J., & Mercer, J. (2016). Learning from the history of disaster vulnerability and resilience research and practice for climate change. *Natural Hazards*, 82, 129-143. https://doi.org/10.1007/s11069-016-2294-0

Kendall, M.G. (1976). Rank Correlation Methods. 4th Ed. Griffin.

Khan, S. D., Gadea, O. C., Tello Alvarado, A., & Tirmizi, O. A. (2022). Surface Deformation Analysis of the Houston Area Using Time Series Interferometry and Emerging Hot Spot Analysis. *Remote Sensing*, 14(15), 3831. https://doi.org/10.3390/rs14153831

Lavell, A., M. Oppenheimer, C. Diop, J. Hess, R. Lempert, J. Li, R. Muir-Wood, and S. Myeong, (2012). Climate change: new dimensions in disaster risk, exposure, vulnerability, and resilience. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the IPCC

Li, C. J., Chai, Y. Q., Yang, L. S., & Li, H. R. (2016). Spatio-temporal distribution of flood disasters and analysis of influencing factors in Africa. *Natural Hazards*, 82, 721-731. https://doi.org/10.1007/s11069-016-2181-8

Machlis, G. E., Román, M. O., & Pickett, S. T. (2022). A framework for research on recurrent acute disasters. Science advances, 8(10), eabk2458. https://doi.org/10.1126/sciadv.abk2458

Marin, G., Modica, M., Paleari, S., & Zoboli, R. (2021). Assessing disaster risk by integrating natural and socio-economic dimensions: A decision-support tool. *Socio-Economic Planning Sciences*, 77, 101032. https://doi.org/10.1016/j.seps.2021.101032

Marin-Ferrer, M., Vernaccini, L. and Poljansek, K., (2017). *Index for Risk Management INFORM Concept and Methodology Report* — Version 2017, EUR 28655 EN, doi:10.2760/094023

Marzi, S., Mysiak, J., Essenfelder, A.H., Pal, J.S., Vernaccini, L., Mistry, M.N., Alfieri, L., Poljansek, K., Marin-Ferrer, M., & Vousdoukas, M. (2021). Assessing future vulnerability and risk of humanitarian crises using climate change and population projections within the INFORM framework. *Global Environmental Change*, 71, 102393. https://doi.org/10.1016/j.gloenvcha.2021.102393

McBean, G., & Rodgers, C. (2010). Climate hazards and disasters: the need for capacity building. *Wiley Interdisciplinary Reviews: Climate Change*, 1(6), 871-884. https://doi.org/10.1002/wcc.77

McLeod, A. I., & McLeod, M. A. (2015). *Package 'Kendall'.* R Software: London, UK.

Mizutori, M., & Guha-Sapir, D. (2020). *Human cost of disasters: An overview of the last 20 years (2000-2019).* Centre for Research on the Epidemiology of Disasters (CRED) and United Nations Office for Disaster Risk Reduction (UNDRR), Belgium and Switzerland. https://www.undrr.org/sites/default/files/inline-files/Human%20Cost%20of%20Disasters%202000-2019%20FINAL.pdf. Retrieved on October 29, 2023

Naheed, S. (2021). Understanding Disaster Risk Reduction and Resilience: A Conceptual Framework. In: Eslamian, S., Eslamian, F. (eds) *Handbook of Disaster Risk Reduction for Resilience.* Springer, Cham. https://doi.org/10.1007/978-3-030-61278-8_1

O'Keefe, P., Westgate, K. & Wisner, B. (1976). Taking the naturalness out of natural disasters. *Nature* 260, 566–567. https://doi.org/10.1038/260566a0

Pal, I., Shaw, R., Shrestha, S., Djalante, R., & Cavuilati, R. A. W. (2021). Toward sustainable development: Risk-informed and disaster-resilient development in

Asia. In *Disaster Resilience and Sustainability* (pp. 1-20). Elsevier. https://doi.org/10.1016/B978-0-323-85195-4.00001-9

Paluszynska, A. (2017). *Structure mining and knowledge extraction from random forest with applications to the cancer genome atlas project*. University of Warsaw Master Thesis.

Paluszynska, A., Biecek, P., and Jiang, Y. (2020). *Explaining and visualizing random forests in terms of variable importance.* R package version 0.10.1, https://github.com/ModelOriented/randomForestExplainer.Last accessed on December 8, 2023

Park, A. S. (2023). Understanding resilience in sustainable development: Rallying call or siren song? *Sustainable Development*, 1–15. https://doi.org/10.1002/sd.2645

Rahman, A. U., & Fang, C. (2019). Appraisal of gaps and challenges in Sendai framework for disaster risk reduction priority 1 through the lens of science, technology and innovation. *Progress in disaster science*, 1, 100006. https://doi.org/10.1016/j.pdisas.2019.100006

Raju, E., Boyd, E., & Otto, F. (2022). Stop blaming the climate for disasters. *Communications Earth & Environment*, 3(1), 1. https://doi.org/10.1038/s43247-021-00332-2

Salvucci, V., & Santos, R. (2020). Vulnerability to natural shocks: Assessing the short-term impact on consumption and poverty of the 2015 flood in Mozambique. *Ecological Economics*, 176, 106713. https://doi.org/10.1016/j.ecolecon.2020.106713

Samaraweera, H. U. S. (2023). Exploring complexities of disaster risk and vulnerability: Everyday lives of two flood-affected communities in Sri Lanka. *Sustainable Development*. https://doi.org/10.1002/sd.2723

Scheffran, J., Link, P. M., & Schilling, J. (2019). Climate and conflict in Africa. In *Oxford Research Encyclopedia of Climate Science*. https://doi.org/10.1093/acrefore/9780190228620.013.557

Shi, P., Yang, X., Xu, W., & Wang, J. A. (2016). Mapping global mortality and affected population risks for multiple natural hazards. *International Journal of Disaster Risk Science*, 7, 54-62. https://doi.org/10.1007/s13753-016-0079-4

Song, Y. (2021). Introduction to Spatial Stratified Heterogeneity Models in R.

Subroto, S., & Datta, R. (2023). Perspectives of racialized immigrant communities on adaptability to climate disasters following the UN Roadmap for Sustainable Development Goals (SDGs) 2030. Sustainable Development. https://doi.org/10.1002/sd.2676

Szabo, S., Nicholls, R. J., Neumann, B., Renaud, F. G., Matthews, Z., Sebesvari, Z., ... & Hutton, C. (2016). Making SDGs work for climate change hotspots. Environment: Science and Policy for Sustainable Development, 58(6), 24-33. https://doi.org/10.1080/00139157.2016.1209016

Thomalla, F., Boyland, M., Johnson, K., Ensor, J., Tuhkanen, H., Gerger Swartling, Å., Han, G., Forrester, J., & Wahl, D. (2018). *Transforming Development and Disaster Risk. Sustainability*, 10(5), 1458. https://doi.org/10.3390/su10051458

Trogrlić, R. S., van den Homberg, M., Budimir, M., McQuistan, C., Sneddon, A., & Golding, B. (2022). Early warning systems and their role in disaster risk reduction. In *Towards the "Perfect" Weather Warning: Bridging Disciplinary Gaps through Partnership and Communication* (pp. 11-46). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-98989-7_2

UNISDR (United Nations International Strategy for Disaster Reduction). (2015). *Sendai framework for disaster risk reduction 2015–2030.* http://www.wcdrr.org/preparatory/post2015. Accessed December 8, 2023

United Nations General Assembly [UNGA] (2016). *Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction.* United Nations General Assembly: New York, NY, USA, 41.

Visser, H., De Bruin, S., Martens, A., Knoop, J., & Ligtvoet, W. (2020). What users of global risk indicators should know. *Global Environmental Change*, 62, 102068. https://doi.org/10.1016/j.gloenvcha.2020.102068

Wang, J. F., Li, X. H., Christakos, G., Liao, Y. L., Zhang, T., Gu, X., & Zheng, X. Y. (2010). Geographical detectors-based health risk assessment and its application in the neural tube defects study of the Heshun Region, China. *International Journal of Geographical Information Science*, 24(1), 107-127. DOI: 10.1080/13658810802443457

Wang, J. F., Zhang, T. L., & Fu, B. J. (2016). A measure of spatial stratified heterogeneity. *Ecological indicators*, 67, 250-256. https://doi.org/10.1016/j.ecolind.2016.02.052

Wen, J., Wan, C., Ye, Q., Yan, J., & Li, W. (2023). Disaster Risk Reduction, Climate Change Adaptation and Their Linkages with Sustainable Development over the Past 30 Years: A Review. *International Journal of Disaster Risk Science*, 14(1), 1-13. https://doi.org/10.1007/s13753-023-00472-3

Wisner, B., Blaikie, P. M., Blaikie, P., Cannon, T., & Davis, I. (2004). *At risk: natural hazards, people's vulnerability and disasters.* Psychology Press.

Yaghmaei, N. (2019). Disasters in Africa: 20 year review (2000–2019). CRED Crunch, (56). https://reliefweb.int/attachments/c4d1cae0-8939-3994-9452-807893a8f8d0/CredCrunch56.pdf

Zhang, M., & Wang, J. (2022). Trend analysis of global disaster education research based on scientific knowledge graphs. *Sustainability*, 14(3), 1492. https://doi.org/10.3390/su14031492

Zhou, Y., Liu, Y., Wu, W., & Li, N. (2015). Integrated risk assessment of multi-hazards in China. *Natural hazards*, 78, 257-280. https://doi.org/10.1007/s11069-015-1713-y

Appendix (Paper 1)

```
#####    R CODES USED FOR MANUSCRIPT SD-23-1585 #####
#TREND ANALYSES SCRIPT
##################################

#Set working Directory
setwd("C:/Users/xxx")

#
# Install the necessary packages
install.packages(c("Kendall", "ggplot2"))

# Load the packages
library(Kendall)
library(ggplot2)

# Input your data
data <- read.csv("trenddataallvars2.csv")
data1 <- read.csv("Vuln_Groups.csv")
data2 <- read.csv("SEVulnerability.csv")
data3 <- read.csv("Natural_Hazard.csv")
data4 <- read.csv("Institutional.csv")
data5 <- read.csv("Infrastructure.csv")
data6 <- read.csv("INFDRI.csv")
data7 <- read.csv("Human_Hazard.csv")

head(data1)

a<-mean(data6$IndicatorScore)
median(data6$IndicatorScore)

# Create box plots with facet wrap for all data components
ggplot(data1, aes(x = IndicatorName, y = IndicatorScore)) +
  geom_boxplot() + facet_grid(~ Region)+ theme(legend.text = element_text(size =
20)) + theme(text = element_text(size = 40))

ggplot(data2, aes(x = IndicatorName, y = IndicatorScore)) +
  geom_boxplot() + facet_grid(~ Region)+ theme(legend.text = element_text(size =
20)) + theme(text = element_text(size = 40))

ggplot(data3, aes(x = IndicatorName, y = IndicatorScore)) +
```

geom_boxplot() + facet_grid(~ Region)+ theme(legend.text = element_text(size = 40)) + theme(text = element_text(size = 40))

ggplot(data4, aes(x = IndicatorName, y = IndicatorScore)) +
geom_boxplot() + facet_grid(~ Region)+ theme(legend.text = element_text(size = 40)) + theme(text = element_text(size = 40))

ggplot(data5, aes(x = IndicatorName, y = IndicatorScore)) +
geom_boxplot() + facet_grid(~ Region)+ theme(legend.text = element_text(size = 40)) + theme(text = element_text(size = 40))

ggplot(data6, aes(x = IndicatorName, y = IndicatorScore)) +
geom_boxplot() + facet_grid(~ Region)+ theme(legend.text = element_text(size = 40)) + theme(text = element_text(size = 40))

ggplot(data7, aes(x = IndicatorName, y = IndicatorScore)) +
geom_boxplot() + facet_grid(~ Region)+ theme(legend.text = element_text(size = 40)) + theme(text = element_text(size = 40))

ggplot(data6, aes(x = IndicatorName, y = IndicatorScore)) +
geom_boxplot()+ theme(legend.text = element_text(size = 40)) + theme(text = element_text(size = 40))

Visualize the data and trend

ggplot(data1, aes(x = INFORMYear, y = IndicatorScore)) +
geom_point() +
geom_line() + facet_wrap(~ Country, nrow = 5) +
theme(axis.text.x = element_text(angle = 30, hjust = 0.5, vjust = 0.5))

ggplot(data6, aes(x = INFORMYear, y = IndicatorScore)) +
geom_point() +
geom_line() + facet_wrap(~ Country, nrow = 5)+
theme(axis.text.x = element_text(angle = 30, hjust = 0.5, vjust = 0.5))

Visualize the data and trend for country and region facets and continental-wide

ggplot(data6, aes(INFORMYear, IndicatorScore)) +
geom_point() + geom_smooth() + facet_wrap(~ Country, nrow = 5)+
theme(axis.text.x = element_text(angle = 30, hjust = 0.5, vjust = 0.5))+
theme(legend.text = element_text(size = 12)) + theme(text = element_text(size = 20))

ggplot(data6, aes(INFORMYear, IndicatorScore)) +

```
  geom_point() + geom_smooth() + facet_wrap(~ Region, nrow = 1)+
  theme(axis.text.x = element_text(angle = 30, hjust = 0.5, vjust = 0.5))+
theme(legend.text = element_text(size = 40)) + theme(text = element_text(size = 40))

ggplot(data6, aes(INFORMYear, IndicatorScore)) +
  geom_point() + geom_smooth()+ theme(legend.text = element_text(size = 40))+
theme(text = element_text(size = 40))    #DR trend for Africa

?linetype

d=data.frame(lt=c("blank", "solid", "dashed", "dotted", "dotdash", "longdash", "twodash",
"1F", "F1", "4C88C488", "12345678"))
ggplot() +
  scale_x_continuous(name="", limits=c(0,1), breaks=NULL) +
  scale_y_discrete(name="linetype") +
  scale_linetype_identity() +
  geom_segment(data=d, mapping=aes(x=0, xend=1, y=lt, yend=lt, linetype=lt))

?geom_smooth
```

#Multi-factor plots - Africa, Country, Region

```
ggplot(data, aes(INFORMYear, IndicatorScore, colour = IndicatorName, linetype =
IndicatorName)) +
  geom_point() +
  geom_smooth(se = FALSE, method = lm)+
  theme(axis.text.x = element_text(angle = 30, hjust = 0.5, vjust = 0.5))+
theme(legend.text = element_text(size = 20))+ theme(text = element_text(size = 30))

ggplot(data, aes(INFORMYear, IndicatorScore, colour = IndicatorName, linetype =
IndicatorName)) +
geom_point() +  geom_smooth(se = FALSE, method = lm) + facet_wrap(~ Country,
nrow = 5)+
  theme(axis.text.x = element_text(angle = 30, hjust = 0.5, vjust = 0.5))+
theme(legend.text = element_text(size = 12))+ theme(text = element_text(size = 20))

ggplot(data, aes(INFORMYear, IndicatorScore, colour = IndicatorName, linetype =
IndicatorName)) +
geom_point() +  geom_smooth(se = FALSE, method = lm) + facet_wrap(~ Region,
nrow = 1)+
  theme(axis.text.x = element_text(angle = 30, hjust = 0.5, vjust = 0.5))+
theme(legend.text = element_text(size = 20))+ theme(text = element_text(size = 30))
```

####Continental trend analyses

```
#Read data
```

```
d1<- read.csv("Vuln_Groups.csv")
d2<- read.csv("SEVulnerability.csv")
d3<- read.csv("Natural_Hazard.csv")
d4<- read.csv("Institutional.csv")
d5<- read.csv("Infrastructure.csv")
d6<- read.csv("INFDRI.csv")
d7<- read.csv("Human_Hazard.csv")

mgm(d1)

# Perform the Mann-Kendall trend analysis
mkrd1 <- MannKendall(d1$IndicatorScore)
mkrd2 <- MannKendall(d2$IndicatorScore)
mkrd3 <- MannKendall(d3$IndicatorScore)
mkrd4 <- MannKendall(d4$IndicatorScore)
mkrd5 <- MannKendall(d5$IndicatorScore)
mkrd6 <- MannKendall(d6$IndicatorScore)
mkrd7 <- MannKendall(d7$IndicatorScore)

#View results
mkrd1
mkrd2
mkrd3
mkrd4
mkrd5
mkrd6
mkrd7

#For S-valuem we compute the summary of the trend results
summary (mkrd1)
summary (mkrd2)
summary (mkrd3)
summary (mkrd4)
summary (mkrd5)
summary (mkrd6)
summary (mkrd7)


# Input your data for regional trend analysis
#Set working Directory
setwd("C:/Users/xxx ")

mkdata1<- read.csv("Central_Africa_Vulg.csv")
```

```
mkdata2<- read.csv("Eastern_Africa_Vulg.csv")
mkdata3<- read.csv("Northern_Africa_Vulg.csv")
mkdata4<- read.csv("Southern_Africa_Vulg.csv")
mkdata5<- read.csv("Western_Africa_Vulg.csv")
mkdata6<- read.csv("Central_Africa_Secvul.csv")
mkdata7<- read.csv("Eastern_Africa_Secvul.csv")
mkdata8<- read.csv("Northern_Africa_Secvul.csv")
mkdata9<- read.csv("Southern_Africa_Secvul.csv")
mkdata10<- read.csv("Western_Africa_Secvul.csv")
mkdata11<- read.csv("Central_Africa_NaHaz.csv")
mkdata12<- read.csv("Eastern_Africa_NaHaz.csv")
mkdata13<- read.csv("Northern_Africa_NaHaz.csv")
mkdata14<- read.csv("Southern_Africa_NaHaz.csv")
mkdata15<- read.csv("Western_Africa_NaHaz.csv")
mkdata16<- read.csv("Central_Africa_Institutional.csv")
mkdata17<- read.csv("Eastern_Africa_Institutional.csv")
mkdata18<- read.csv("Northern_Africa_Institutional.csv")
mkdata19<- read.csv("Southern_Africa_Institutional.csv")
mkdata20<- read.csv("Western_Africa_Institutional.csv")
mkdata21<- read.csv("Central_Africa_infrastructure.csv")
mkdata22<- read.csv("Eastern_Africa_infrastructure.csv")
mkdata23<- read.csv("Northern_Africa_infrastructure.csv")
mkdata24<- read.csv("Southern_Africa_infrastructure.csv")
mkdata25<- read.csv("Western_Africa_infrastructure.csv")
mkdata26<- read.csv("Central_Africa_DRI.csv")
mkdata27<- read.csv("Eastern_Africa_DRI.csv")
mkdata28<- read.csv("Northern_Africa_DRI.csv")
mkdata29<- read.csv("Southern_Africa_DRI.csv")
mkdata30<- read.csv("Western_Africa_DRI.csv")
mkdata31<- read.csv("Central_Africa_HuHaz.csv")
mkdata32<- read.csv("Eastern_Africa_HuHaz.csv")
mkdata33<- read.csv("Northern_Africa_HuHaz.csv")
mkdata34<- read.csv("Southern_Africa_HuHaz.csv")
mkdata35<- read.csv("Western_Africa_HuHaz.csv")
```

Perform the Mann-Kendall trend analysis

```
mk_result1 <- MannKendall(mkdata1$IndicatorScore)
mk_result2 <- MannKendall(mkdata2$IndicatorScore)
mk_result3 <- MannKendall(mkdata3$IndicatorScore)
mk_result4 <- MannKendall(mkdata4$IndicatorScore)
mk_result5 <- MannKendall(mkdata5$IndicatorScore)
mk_result6 <- MannKendall(mkdata6$IndicatorScore)
mk_result7 <- MannKendall(mkdata7$IndicatorScore)
mk_result8 <- MannKendall(mkdata8$IndicatorScore)
```

```
mk_result9 <- MannKendall(mkdata9$IndicatorScore)
mk_result10 <- MannKendall(mkdata10$IndicatorScore)
mk_result11 <- MannKendall(mkdata11$IndicatorScore)
mk_result12 <- MannKendall(mkdata12$IndicatorScore)
mk_result13 <- MannKendall(mkdata13$IndicatorScore)
mk_result14 <- MannKendall(mkdata14$IndicatorScore)
mk_result15 <- MannKendall(mkdata15$IndicatorScore)
mk_result16 <- MannKendall(mkdata16$IndicatorScore)
mk_result17 <- MannKendall(mkdata17$IndicatorScore)
mk_result18 <- MannKendall(mkdata18$IndicatorScore)
mk_result19 <- MannKendall(mkdata19$IndicatorScore)
mk_result20 <- MannKendall(mkdata20$IndicatorScore)
mk_result21 <- MannKendall(mkdata21$IndicatorScore)
mk_result22 <- MannKendall(mkdata22$IndicatorScore)
mk_result23 <- MannKendall(mkdata23$IndicatorScore)
mk_result24 <- MannKendall(mkdata24$IndicatorScore)
mk_result25 <- MannKendall(mkdata25$IndicatorScore)
mk_result26 <- MannKendall(mkdata26$IndicatorScore)
mk_result27 <- MannKendall(mkdata27$IndicatorScore)
mk_result28 <- MannKendall(mkdata28$IndicatorScore)
mk_result29 <- MannKendall(mkdata29$IndicatorScore)
mk_result30 <- MannKendall(mkdata30$IndicatorScore)
mk_result31 <- MannKendall(mkdata31$IndicatorScore)
mk_result32 <- MannKendall(mkdata32$IndicatorScore)
mk_result33 <- MannKendall(mkdata33$IndicatorScore)
mk_result34 <- MannKendall(mkdata34$IndicatorScore)
mk_result35 <- MannKendall(mkdata35$IndicatorScore)

#View results
mk_result1
summary (mk_result1)
.
.
.
mk_result35

####################### END
#########################
```

#VARIABLE IMPORTANCE ANALYSES – DECADAL MEAN

#SCRIPT FOR DETERMINATION OF IMPORTANT VARIABLES CONTRIBUTING TO AFRICAN COUNTRIES' DISASTER RISK

```
#################    DECADAL MEAN ANALYSES
#################

#Load/install libraries
install.packages("randomForest")
library(randomForest)
library(randomForestExplainer)

#Load data
library(readr)
data <- read_csv("Decadal_mean_trend_AFR.csv")
data
as.data.frame(data)

#train a forest of B=500 trees (default value of the mtry parameter of this function),
#with option localImp = TRUE. The forest is supposed to predict the median riskindex
based on its characteristics.

set.seed(2017)
forest <- randomForest(INFORMRiskIndex ~., data = data, localImp = TRUE, na.rm =
TRUE)
forest

plot(forest)

min_depth_frame <- min_depth_distribution(forest)
save(min_depth_frame, file = "min_depth_frame7.rda")
load("min_depth_frame7.rda")
head(min_depth_frame, n = 10)

plot_min_depth_distribution(forest) # gives the same result as below but takes longer
plot_min_depth_distribution(min_depth_frame)

#Various variable importance measures
#To further explore variable importance measures we pass our forest to
measure_importance function and get the following data frame (we save and load it from
memory to save time):

importance_frame <- measure_importance(forest)
save(importance_frame, file = "importance_frame7.rda")
load("importance_frame7.rda")
importance_frame
```

```
plot_multi_way_importance(forest, size_measure = "no_of_nodes") # gives the same
result as below but takes longer
plot_multi_way_importance(importance_frame, size_measure = "no_of_nodes")

plot_multi_way_importance(importance_frame, x_measure = "mse_increase",
y_measure = "node_purity_increase", size_measure = "p_value", no_of_labels = 12)

plot_importance_ggpairs(forest) # gives the same result as below but takes longer
plot_importance_ggpairs(importance_frame)

plot_importance_rankings(forest) # gives the same result as below but takes longer
plot_importance_rankings(importance_frame)

(vars <- important_variables(forest, k = 10, measures = c("mean_min_depth",
"no_of_trees"))) # gives the same result as below but takes longer

interactions_frame <- min_depth_interactions(forest, vars)
save(interactions_frame, file = "interactions_frame7.rda")
load("interactions_frame7.rda")
head(interactions_frame[order(interactions_frame$occurrences, decreasing = TRUE), ])

plot_min_depth_interactions(forest) # calculates the interactions_frame for default
settings so may give different results than the function below depending on our settings
and takes more time
plot_min_depth_interactions(interactions_frame)

interactions_frame <- min_depth_interactions(forest, vars, mean_sample =
"relevant_trees", uncond_mean_sample = "relevant_trees")
save(interactions_frame, file = "interactions_frame_relevant7.rda")
load("interactions_frame_relevant7.rda")
plot_min_depth_interactions(interactions_frame)



explain_forest(forest, interactions = TRUE, data = data)

#######################    END
#########################
```

#VARIABLE IMPORTANCE ANALYSES – DECADAL

```
#######################################
#SCRIPT FOR DETERMINATION OF IMPORTANT VARIABLES CONTRIBUTING
TO AFRICAN COUNTRIES' DISASTER RISK
```

```
##################    DECADAL ANALYSES
##################

#Load/install libraries
install.packages("randomForest")
library(randomForest)
library(randomForestExplainer)

#Load data
library(readr)
data <- read_csv("Trend_data_AFR_LATEST2NA.csv")
data
as.data.frame(data)

#train a forest of B=500 trees (default value of the mtry parameter of this function),
#with option localImp = TRUE. The forest is supposed to predict the median riskindex
based on its characteristics.

set.seed(2017)
forest <- randomForest(INFORM~ ., data = data, localImp = TRUE, na.rm = TRUE)
forest

plot(forest)

min_depth_frame <- min_depth_distribution(forest)
save(min_depth_frame, file = "min_depth_frame7.rda")
load("min_depth_frame7.rda")
head(min_depth_frame, n = 10)

plot_min_depth_distribution(forest) # gives the same result as below but takes longer
plot_min_depth_distribution(min_depth_frame)

#Various variable importance measures
#To further explore variable importance measures we pass our forest to
measure_importance function and get the following data frame (we save and load it from
memory to save time):

importance_frame <- measure_importance(forest)
save(importance_frame, file = "importance_frame7.rda")
load("importance_frame7.rda")
importance_frame

plot_multi_way_importance(forest, size_measure = "no_of_nodes") # gives the same
result as below but takes longer
```

```
plot_multi_way_importance(importance_frame, size_measure = "no_of_nodes")

plot_multi_way_importance(importance_frame, x_measure = "mse_increase",
y_measure = "node_purity_increase", size_measure = "p_value", no_of_labels = 12)

plot_importance_ggpairs(forest) # gives the same result as below but takes longer
plot_importance_ggpairs(importance_frame)

plot_importance_rankings(forest) # gives the same result as below but takes longer
plot_importance_rankings(importance_frame)

(vars <- important_variables(forest, k = 10, measures = c("mean_min_depth",
"no_of_trees"))) # gives the same result as below but takes longer

interactions_frame <- min_depth_interactions(forest, vars)
save(interactions_frame, file = "interactions_frame7.rda")
load("interactions_frame7.rda")
head(interactions_frame[order(interactions_frame$occurrences, decreasing = TRUE), ])

plot_min_depth_interactions(forest) # calculates the interactions_frame for default
settings so may give different results than the function below depending on our settings
and takes more time
plot_min_depth_interactions(interactions_frame)


interactions_frame <- min_depth_interactions(forest, vars, mean_sample =
"relevant_trees", uncond_mean_sample = "relevant_trees")
save(interactions_frame, file = "interactions_frame_relevant7.rda")
load("interactions_frame_relevant7.rda")
plot_min_depth_interactions(interactions_frame)


explain_forest(forest, interactions = TRUE, data = data)

########################    END
##########################
```

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Contributor Role	Doktorand/in/ *Doctoral student*	Co-Autor/in 1/ *Co-author 1*	Co-Autor/in 2/ *Co-author 2*
Name, first name	Eze, Emmanuel	Siegmund, Alexander	
Methodology	✓		
Software			
Validation			
Formal analysis	✓		
Investigation	✓		
Resources	✓	✓	
Data Curation	✓		
Writing-Original Draft	✓		
Writing-Review&Editing	✓	✓	
Visualization	✓		
Supervision		✓	
Project administration	✓	✓	
Funding acquisition	✓		

***Kategorien des CRediT (Contributor Roles Taxonomy, https://credit.niso.org/)*

Hiermit bestätige ich, dass alle obigen Angaben korrekt sind/*I confirm that all declarations made above are correct.*

Unterschrift/*Signature* Doktorand/in/*Doctoral student* Co-Autor/in 1/*Co-author 1* Co-Autor/in 2/*Co-author 2*

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Alexander Siegmund — Name/*Name*

Unterschrift/*Signature*

29.07.2024 — Datum/*Date*

2

"In the face of impending catastrophe, whose warning signs are already unbearably disastrous, weak action is unwise. No action is dangerous." ~ William Ruto

II.2. Analyzing Important Disaster Risk Factors for Enhanced Policy Responses in Perceived at-Most-Risk African Countries

Abstract

The foremost priority of the Sendai Framework for Disaster Risk Reduction (SFDRR) is the increased understanding of disaster risk and strengthening its management. Detailed insights into African disaster risk drivers and assessment of policies for Disaster Risk Reduction (DRR) are sparse, hence this study. Using the Index for Risk Management (INFORM) data for 2022, this study determines important disaster risk drivers in Africa using a random forest machine learning model. Violent conflicts, current and projected, emerge as the only hazard factor significantly predictive of disaster risk in Africa, from the analyzed data. Other factors are mostly the sub-components of lack of coping capacity. Furthermore, 25 policies of the 10 countries of very high disaster risk were analyzed to evaluate their inclusion of pre-identified disaster risk factors. The findings of this study depart from the viewpoint of giving natural hazards greater attention in African disaster risk literature. Moreover, identified disaster risk drivers in Africa coincide with the social dimension of disasters, and broader continental developmental and policy issues. As Africa grapples with the complex interplay of environmental, socioeconomic, and conflict-related factors shaping disaster risk, the imperative arises for the development and implementation of comprehensive policies aimed at poverty and vulnerability-reduction to foster resilience across the region.

Keywords: Africa; coping capacity; disaster risk drivers; disaster risk reduction; human hazards; natural hazards; violent conflicts; vulnerability

II.2.1. Introduction

The integrity of sustainable development faces an inherent threat from disasters, often stemming from a convergence of hazards, vulnerability, and a lack of coping mechanisms. Vlachogiannis et al. (2022) underscore the exacerbating impact of climate change on associated hazards and their consequences. Concurrently, Nicodemus and Dennis (2021) emphasize that deficient coping capabilities and heightened vulnerabilities amplify the risks, losses, and damages caused by disasters, especially in developing economies. Similarly, Eze and Siegmund (2023) specify that the literature lacks emphasis on specific components of vulnerability and lack of coping capacity, despite their significant contribution to fueling disaster risk. These circumstances pose a direct challenge to comprehensive frameworks, such as the United Nations Agenda 2030, the Sendai Framework for Disaster Risk Reduction (SFDRR), and the Agenda 2063 of the African Union, which ambitiously strive for human well-being, peace, and prosperity within the realms of environmental and economic sustainability.

Africa stands out among the most vulnerable and least resilient regions to disasters, as highlighted in prior research. For example, Manyena (Manyena, 2016) emphasizes that factors like poverty, climate change, rapid urbanization, and structural transformation significantly exacerbate the impacts of natural hazards in this region. Additionally, Paul et al. (2022) estimate that disasters have inflicted various losses on over half a billion people in Africa over the past five decades. The hindrances posed by disaster risks have notably hampered developmental progress in Africa, attributed to deficiencies in risk identification, knowledge management, and governance, as highlighted by The African Union (2004).

Subsequent reports and studies, including those by Bhavnani et al. (2008), and Tiepolo and Braccio (2020), reaffirm these critical gaps in risk identification and assessment within the African context. These shortcomings significantly compromise the availability of essential information required for effective disaster risk reduction (DRR) and management, as noted by van Niekerk et al. (2020), potentially obstructing the attainment of the SFDRR 2015–2030 goals if not adequately addressed.

This study resonates with the advocacy for paradigm shifts emphasized by Kimengsi and Mbih (2022), advocating for a comprehensive understanding of underlying disaster risk factors. Such understanding is essential in facilitating effective risk identification, reduction, and resilience enhancement in sub-Saharan Africa. Addressing these risk factors is imperative to counteract the failure to mitigate the fundamental drivers of disaster risks, as highlighted by Keating et al. (2017). A recent study by Eze and Siegmund (2024) presents a comprehensive analysis of disaster risk trends, hotspots, factors, and their interaction effects on disaster risks across Africa, utilizing a decade-long dataset.

Notably, the literature lacks sufficient evaluations of African disaster risk plans. Tiepolo and Braccio (2020) undertook a policy assessment encompassing the development plans of 21 African nations, revealing the absence of localized characterization and widespread omission of risk reduction objectives within these plans. Additionally, earlier observations about Africa by van Niekerk (2015) have reported the inadequacies of countries' disaster risk governance in aligning with the goals outlined in the defunct Hyogo Framework for Action, indicating a lack of responsiveness in this domain.

This study is driven by the overarching question: How well do relevant policies and national action plans incorporate disaster risk drivers? The need for data-driven insights into underlying disaster risk factors becomes evident as Kimengsi and Mbih (2022) suggest, addresses gaps and bolsters resilience against hazards, aligning with DRR objectives. Furthermore, the assessment of national policies like DRR policies, Nationally Determined Contributions (NDCs), and National Adaptation Programmes of Action (NAPAs) in the context of these disaster risk factors yields valuable insights into the effectiveness of crucial policies. The phrase 'core policies' is used to collectively refer to these three policies in the subsequent sections of the paper. As highlighted by Bello et al. (2021), policy assessments extend beyond hazard evaluations; they serve to diminish vulnerability and prompt public engagement in DRR efforts.

Consequently, this study seeks to initiate an assessment of the responsiveness of core policies in addressing disaster risk drivers in Africa. Initially, we identify disaster risk drivers using the 2022 Index for Risk Management (INFORM) data to assess their inclusion levels within relevant core policies. Subsequently, a content analysis of core policies from countries rated as very high in the disaster risk index is performed. The countries selected were chosen for expediency in providing an initial overview rather than serving as a representative sample for the study.

II.2.2. Potential Contributions of This Study

The study holds potential contributions that can significantly impact DRR efforts in Africa. Firstly, it offers unique insight into the fundamental factors driving disaster risk in the continent, empowering policymakers with specific knowledge to refine and bolster existing DRR policies. Highlighting the pivotal role of vulnerability and the underrepresentation of certain hazards within core policies lays the groundwork for more focused and targeted policy interventions.

Secondly, this research broadens the conventional understanding of disaster risks in Africa. The findings shift the lens from solely natural hazards to encompassing human-induced hazards and social vulnerabilities. This holistic perspective prompts a more comprehensive approach to disaster risk assessment and mitigation, emphasizing the critical need to address social, economic, and governance-related factors to effectively manage disaster risks.

Moreover, the study emphasizes inclusive and adaptive policy frameworks, which resonate with international development goals like the SFDRR and the Sustainable Development Goals of Agenda 2030. By advocating for policies that encompass the multifaceted nature of disaster risks, the study aligns with global efforts towards sustainable development and resilience-building in vulnerable regions.

Furthermore, this research lays a foundation for future investigations. It sets the stage for detailed country-specific studies, encouraging deeper exploration of disaster risk drivers across different African regions. This approach promises to unveil more relatable insights into region-specific vulnerabilities, thereby enriching the understanding of disaster risk factors and offering tailored solutions for more effective DRR strategies.

II.2.3. Materials and Methods

II.2.3.1. Data

This study utilizes data from the 2022 INFORM disaster risk index and various policy documents. Downloaded in the XLS format, the INFORM dataset encompasses all variables detailed in Figure II.2–1 and was sourced from https://drmkc.jrc.ec.europa.eu/inform-index/ (accessed on 15 December 2022). The INFORM dataset is curated by The Joint Research Center of the European Commission, serving as the primary scientific resource for multiple stakeholders, including the humanitarian and development sectors, donors, and technical partners.

This global open-source tool aims to offer an objective and transparent understanding of risks associated with humanitarian crises. A comprehensive report of the concepts, procedure and methodology involved in generating the INFORM dataset is contained in Marin-Ferrer et al. (2017). Also, Eze and Siegmund (2024) systematically conceptualized all key components of the INFORM dataset, deeming the data reliable and consistent for decadal-level analyses of disaster risk drivers in Africa. Readers are to refer to these materials to obtain further clarity.

Our reliance on the INFORM dataset is reinforced by previous studies affirming its reliability. Egawa et al. (2018) express confidence in the INFORM dataset as a robust representation of the disaster risk index. Additionally, Birkmann et al. (2022) conducted analyses demonstrating a high level of inherent consistency among indicators, reflected in near-perfect reliability scores of 0.948 for Cronbach Alpha and 0.954 for Guttman Lambda.

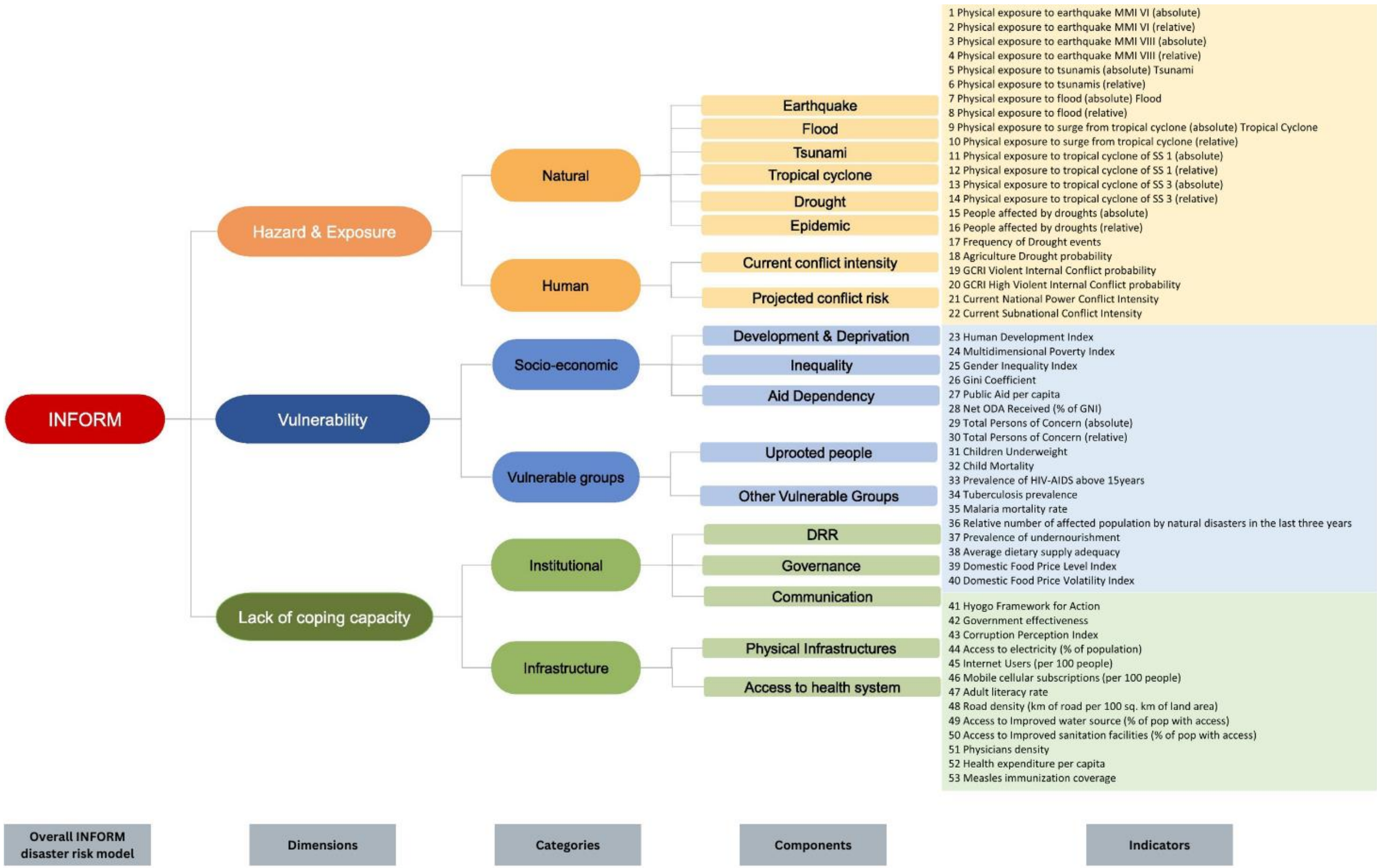

Figure II.2–1: Components of the INFORM model
Source: Eze and Siegmund (2023)

Moreover, our study involved the analysis of core policies from ten African countries exhibiting a very high INFORM disaster risk index. These documents include DRR policies, Nationally Determined Contributions (NDC), and National Adaptation Programmes of Action for Climate Change (NAPA). Detailed information regarding these documents is presented in Table II.2–1, with full references provided subsequently in Supplementary Table II.2–A1. We deem these documents reliable and suitable for this study as they are published by national agencies of the respective countries following global frameworks.

Table II.2–1: Publication year of policy documents used for the content analyses in this study.

	Country	Disaster Risk Reduction Policy	Nationally Determined Contribution	National Adaptation Programme of Action for Climate Change *
1	Central African Republic (CAR)	None	2021 **	2008 **
2	Chad	None	2021 **	2010 **
3	DR Congo (DRC)	2012 **	2021 **	2006 **
4	Ethiopia	2013	2021	2007
5	Mali	2010 **	Inaccessible: Could not translate	2007 **
6	Mozambique	2017 **	2021	2007
7	Niger	None	2021 **	2006 **
8	Nigeria	2010	2021	2011
9	Somalia	None	2021	2013
10	South Sudan	2018	2021	2016

Notes

*Sourced from https://unfccc.int/topics/resilience/workstreams/national-adaptation-programmes-of-action/napas-received (accessed on 15 December 2022);

** Document Machine-translated into the English Language before the content analyses

II.2.3.2. Data Analyses

II.2.3.2.1. Variable Importance Analysis

Variable importance analysis was conducted using the randomForestExplainer package developed by Paluszynska et al. (2022) in R version 4.2.1. This package employs a model that identifies and ranks the most significant variables in random forest (RF) analyses based on their predictive capability of the dependent variable.

We consider the randomForestExplainer package an ancillary tool to retrieve further information from an RF analysis.

An RF consists of ensembles of recursive partitioning tree models, introducing randomization to enhance predictive performance (Breiman, 2001). Its advantages include compatibility with diverse data types, flexibility with non-parametric distributions, and the ability to capture complex relationships without prior assumptions about functional forms, hence its increasing application in the social sciences.

However, the limited interpretability of RF is acknowledged by Levi (Levi, 2021) who describes a "black box" challenge in explaining RF outcomes, suggesting that only ancillary tools can "white box" the RF results for relevant information. Hence, we use Paluszynska's (Paluszynska et al. 2022) package to extract useful information on important variables on disaster risk index from INFORM data for 2022.

Our study incorporated all hazard, vulnerability, and lack of coping capacity factors from the INFORM data for Africa as independent variables, while the INFORM risk index served as the dependent variable (Figure II.2–1). An RF regression model consisting of 500 trees was generated to determine the minimal depth distribution within the generated forest via the min_depth_distribution function. The model computed various importance measures, including the number of nodes, accuracy decrease (MSE increase), Gini decrease (node purity increase), number of trees, times_a_root, and p-value. Technical details regarding the RF model operations are available in Paluszynska (2017) for a deeper understanding. The resulting important disaster risk drivers in Africa are presented in the results section.

II.2.3.2.2. Content Analyses of Core Policies

Content analysis was conducted on the documents listed in Table II.2–1 to determine the extent of their inclusion of disaster risk-driving factors identified through the RF variable importance analyses within selected policies. Specifically, the analysis focused on ten countries characterized by very high disaster risk indexes according to the INFORM data. The selection of these countries for the present study does not aim at generalization to other African nations. Instead, they serve as unique case studies to explore the topic as a pioneer study.

The study employed a summative content analysis approach following the methodology outlined by Hsieh and Shannon (2005). This technique involves counting specific keywords or concepts in the selected documents to derive contextual insights. Prior to data analysis, keywords were selected and later refined based on the components corresponding to disaster risk variables, including hazards, vulnerability, and lack of coping capacity. These keywords, aligned with the

INFORM Methodology (Marin-Ferrer et al., 2017), are outlined in Table II.2–2, presenting the keywords used and their significance as positive indicators in the content analyses.

To ensure the reliability of the coding scheme, an inter-rater reliability test was conducted. An independent reviewer analyzed six randomly selected policy documents using our predefined keywords. The analysis demonstrated a substantial agreement of 90.73% in coding (Supplementary Table II.2–A2), yielding an "almost perfect" Cohen kappa rating according to the classification of McHugh (2012).

Table II.2–2: Coding schematics used for keyword search hits in selected policy documents.

Keywords (bolded)/Concepts Used for Search	Intended Contexts to Count
Conflict	
Conflict/war	Armed violent conflict episodes or war
Uprooted people	
Refugees	Refugees
Internally/Externally Displaced persons—IDPs/Displaced population	Internally/Externally Displaced persons—IDPs/Displaced population
Vulnerable Groups	
Disability	People with disability
Disease/illness	People living with diseases such as HIV, etc.
Other limitations (e.g., pregnancy, lactating mothers, children, and elderly/old/aged people)	Pregnant women, lactating mothers, children, and elderly/old/aged people
Minorities/indigenous peoples	Minorities/indigenous peoples
Rural area population/dwellers	Rural area population/dwellers
Development & Deprivation	
Social/economic development	Social, economic and infrastructural development
Sustainable development	Sustainable development
Life expectancy	Life expectancy
Education	Education
Income	Income
Living standards	Living standards
Health	Health
Poor people/households	Poor people/households

Deprivations	Deprivations
Physical infrastructure	
Roads	Roads
Water source/access/drinking water	Water source/access/drinking water
Sanitation facilities	Sanitation facilities
Governance	
Governance	Governance
Corrupt/ion	Corrupt/ion
Communication	
Electricity	Electricity
Internet	Internet
Mobile phone/cellphone/landline/ telephone	Mobile phone/cellphone/landline/telephone
Access to healthcare	
Physicians/Doctors	Physicians/Doctors
Hospital/Clinic	Hospital/Clinic
Immunisation/immunization	Immunisation/immunization

Note: Bolded text represent the disaster risk driver

II.2.4. Results

II.2.4.1. Disaster Risk Index of African Countries

From the 2022 INFORM disaster risk index, ten African countries had very high disaster risk indexes, while twenty countries were categorized as having high-risk rankings. Additionally, eighteen countries fell into the medium-risk category. Conversely, a subset of six countries, namely Botswana, Cabo Verde, Mauritius, Sao Tome and Principe, Seychelles, and Tunisia, exhibited very low to low-risk indexes. Notably, four of these countries are primarily island states (Figure II.2–2).

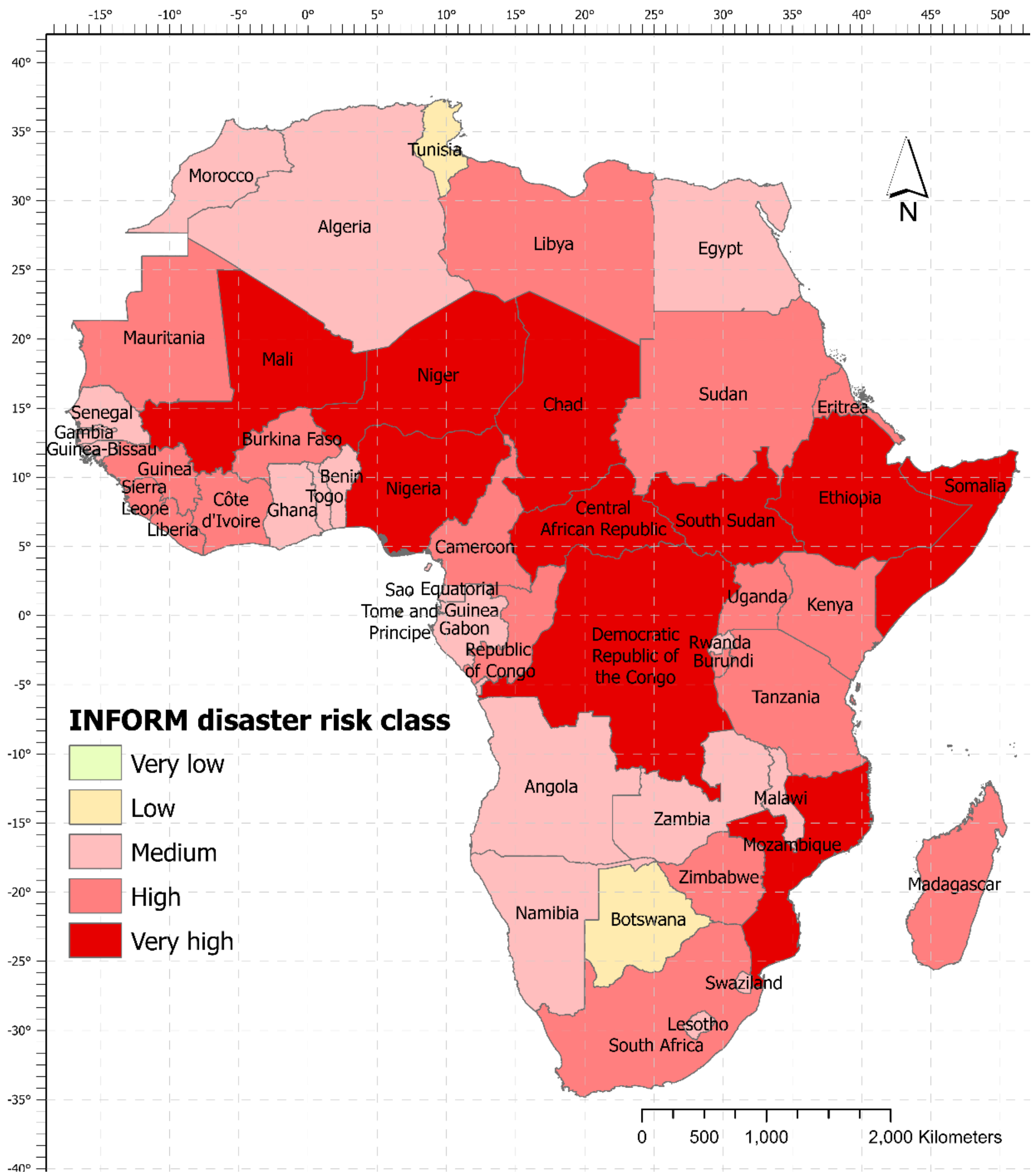

Figure II.2–2. Disaster risk index classes of African countries.
Source: INFORM dataset, 2022

II.2.4.1.1. Important Variables of Disaster Risk in Africa

Based on our analysis of the INFORM data, the Random Forest (RF) model consisted of 500 trees without a specified limit on the maximum number of terminal nodes in a tree. The model tested eight variables at each split. The RF regression algorithm achieved a high accuracy, explaining 86% of the variance of listed variables.

II.2.4.1.2. Variable Importance Measures: Distribution of Minimal Depth

The minimal depth of a variable signifies its proximity to the root of the tree and its correlation with the dependent variable (risk index). In Figure 3, the top 10 variables display lower mean minimal depths, indicating trees were split up to a depth of 13. Figure 4 illustrates the notable variables selected from the RF analysis (Figure II.2–1), emphasizing their closeness to the root of the tree and their correlation with the overall risk index.

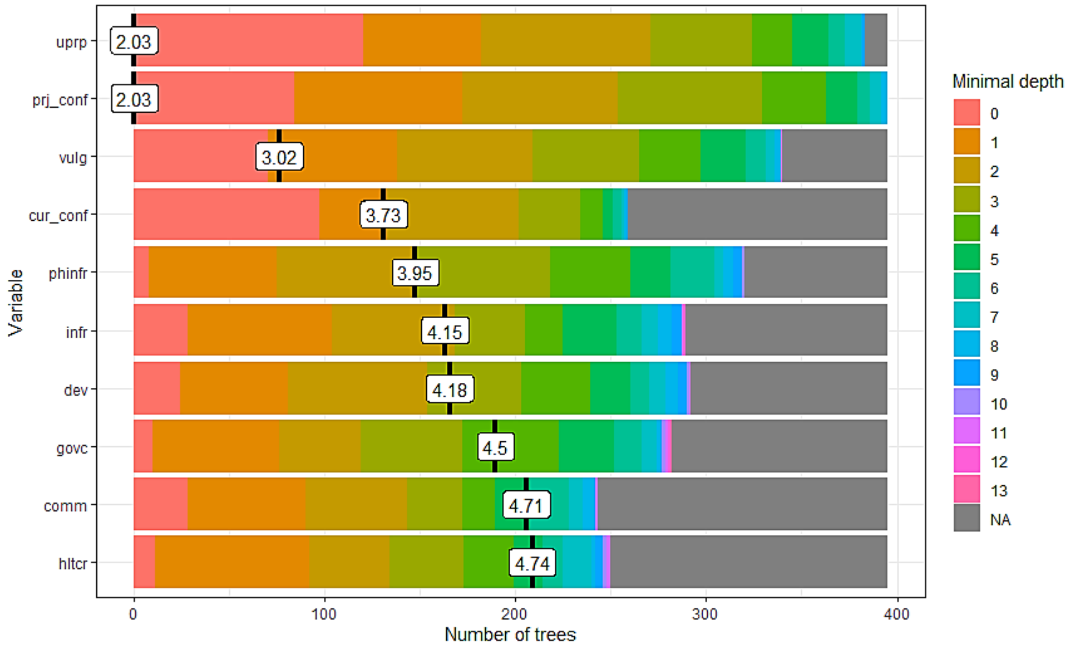

Figure II.2–3. Distribution of minimal depth among the forest trees. A black vertical bar marks the mean of the distribution, and a value label is inscribed. Abbreviations: uprp—Uprooted people; prj_conf—Projected Conflict Risk; vulg—Vulnerable Groups; cur_conf—Current Highly Violent Conflict Intensity; phinfr—Physical infrastructure; infr—Infrastructure; dev—Development & Deprivation; govc—Governance; comm—Communication; hltcr—Access to health care. Source: Own analysis

Therefore, the ten key disaster risk drivers identified by the variable importance analyses include projected conflict risk, current highly violent conflict intensity, development and deprivation, vulnerable groups, uprooted people, governance, infrastructure, communication, physical infrastructure, and access to health care (Figure II.2–4).

Figure II.2–4. Resulting important variables of disaster risk index for Africa. Source: Own analysis

II.2.4.2. Important Disaster Risk Factors Included within Analysed Policies

Among the 25 analyzed policy documents from the ten high-risk countries, a total of 3958 keywords were identified. These keywords were categorized into the hazard, vulnerability, and lack of coping capacity concepts, representing 4.27%, 64.96%, and 30.77% respectively of the total keyword count in the policies. For a comprehensive breakdown of the keyword counts per risk factor and sub-components, please refer to Table 3. Also, more details are contained in Supplementary Table II.2–A3.

Table II.2–3. Total inclusion of disaster risk driver keywords within selected policies.

Risk Factor	Total Count	Components	Total Count	Percentage (%)
Hazards	169	Violent conflict	169	4.27
Vulnerability	2571	Uprooted people	100	2.53
		Vulnerable Groups	291	7.35
		Development & Deprivation	2180	55.087
Lack of coping capacity	1218	Infrastructure	717	18.12
		Governance	122	3.08
		Communication	319	8.06
		Access to healthcare	60	1.52
Total	**3958**		**3958**	**100**

Core policies of the ten African countries rated as having very high disaster risk (or at-most-risk) did not significantly integrate (human) hazard drivers identified in this study. Only a few policies from nations like Somalia, South Sudan, and the Democratic Republic of Congo (DRC) displayed limited mentions of conflict-related aspects. In contrast, vulnerability-related concepts were more commonly incorporated, followed by indicators depicting a lack of coping capacity (Table II.2–3). Moreover, a weak positive correlation was observed; a higher risk index corresponded to increased counts of the key concepts included in the examined policies (R = 0.17, Figure 5). Hence, countries with higher disaster risk indexes incorporated more concepts related to disaster risk drivers within their policies.

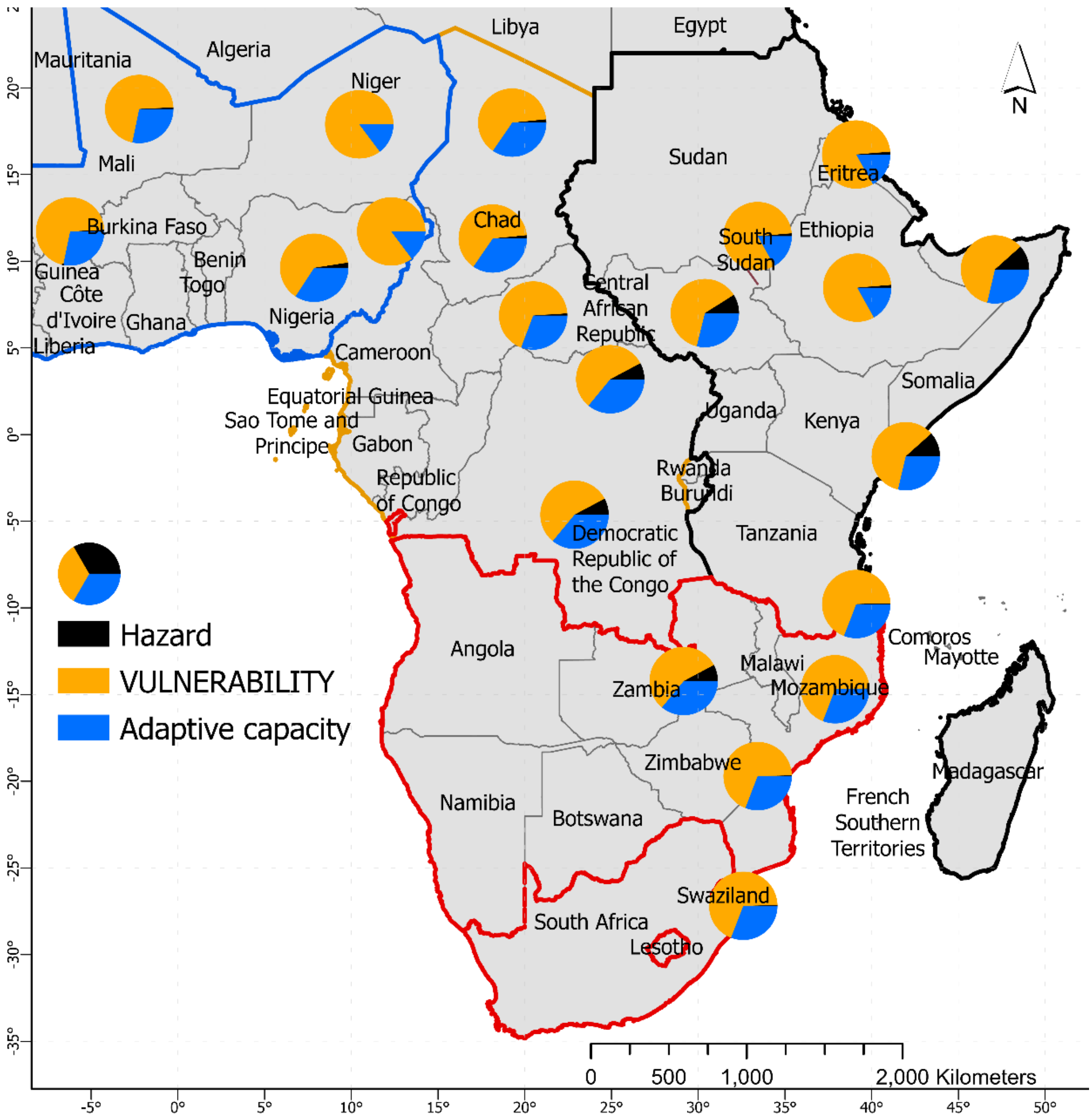

Figure II.2–5. Disaster risk keyword-inclusion rates in selected policies for African countries of very high disaster risk index.

Source: Own analysis.

II.2.5. Discussion

II.2.5.1. Disaster Risk and Important Drivers in Africa

A significant portion of African countries, precisely 20 out of the total, placed at high levels on the disaster risk index. Interestingly, half of this subset, accounting for 10 countries, falls into the classification of very high risk. This underscores the widespread vulnerability and exposure to disasters across the continent. Conversely, only six African countries, mainly island states, demonstrate very low to low risk indexes. According to the UNISDR (2015) definition of disaster risk, these 30 countries face elevated probabilities of experiencing loss of life, injuries, and damages due to disasters.

Interestingly, findings derived from the INFORM data slightly contrast with a similar risk index presented by Welle and Birkmann (2015), which considers exposure, susceptibility, coping, and adaptive capacity. Notably, countries categorized as having medium risks by the World Risk Index (WRI) of Welle and Birkmann (2015), such as Uganda, Kenya, South Africa, the Central African Republic (CAR), and the DRC, are designated as high to very high risk based on the INFORM dataset. This variation in results may be attributed to disparities in data sources and methodologies between the INFORM and WRI assessments.

The key drivers of African countries' disaster risk index encompass factors such as uprooted populations, anticipated conflict risks, vulnerable groups, prevailing highly violent conflicts, physical infrastructure, development status, deprivation levels, governance effectiveness, communication networks, and access to healthcare. Notably, among these factors, five are associated with the lack of coping capacity, three with vulnerability, and two with human (rather than natural) hazards. Factors such as governance, migration, and conflicts have been previously identified as drivers of environmental challenges in parts of Sub-Saharan Africa by the Global Environment Facility (Strategic Country Cluster Evaluation (SCCE): Sahel and Sudan-Guinea Savanna biomes, 2021).

Consequently, lack of coping capacity and vulnerability stand out as the primary drivers of disaster risk in Africa. This aligns with the findings reported by Birkmann and Welle (2016), who indicate that African nations exhibit the highest vulnerability on a global scale. Additionally, the projection of Masson-Delmotte (2018) regarding Africa bearing an increasing share of the globally exposed and vulnerable population to the impacts of global warming remains relevant. In general, our findings are in harmony with Imperiale and Vanclay's (Imperiale & Vanclay, 2021) perspective on the social aspects of risks. We therefore argue that in Africa, natural hazards, in isolation, are not the primary triggers of disasters; rather, the complex interplay of various social factors. Many of these factors, identified as disaster risk drivers in our study, contribute significantly to the dynamics of disasters on the continent.

Violent conflicts, whether ongoing or anticipated in the future, emerge as critical predictors of disaster risk in Africa, demanding substantial attention and concern. These conflicts often find roots and are intricately linked to multifaceted issues like poverty, human rights violations, governance challenges, ethnic marginalization, and the proliferation of small arms (Annan, 2014). Remarkably, these conflict-related factors exhibit close associations with crucial elements contributing to vulnerability and lack of coping capacity, such as vulnerable groups, development status, deprivation levels, and governance quality.

Importantly, most of these elements share similarities with the conditions of poverty. The literature presents various perspectives on the relationship between poverty and conflicts in Africa. While Annan (2014) emphasizes poverty as a primary driver of conflicts, recent findings by Okunlola and Okafor (2022) suggest that poverty may stimulate rather than cause conflicts, attributing political, structural, and sociological factors as primary drivers. Furthermore, Witmer et al. (2017) forecast that inadequate improvements in political rights within sub-Saharan Africa, coupled with population growth and rising temperatures, could escalate violence in the region.

Climate change has emerged as a significant contributing factor to conflicts in Africa, primarily perpetuating existing conflicts rather than initiating new ones, as noted by van Weezel (2020). The impact of varying degrees of climate change on critical aspects like agriculture, resource scarcity, and migration significantly heightens armed conflicts across the continent (Cappelli et al., 2022). Similarly, Burke et al. (2020) present compelling evidence linking climate change, especially rising temperatures, to various violent outcomes such as large-scale group conflicts, interpersonal conflicts, and self-harm across continents and various timeframes.

Notably, these influences may differ by geographic location in Africa. The findings of Hoch et al. (2021) suggest that changing climatic conditions elevate conflict risks in Northern and large parts of Eastern Africa while potentially reducing conflict risks in the West and northern Sahel regions. It is crucial to recognize that violent conflicts, in turn, exacerbate the vulnerability of populations, emphasizing the intricate relationship between environmental changes, conflicts, and increased societal vulnerability.

Conflicts have a profound effect on displacing populations, particularly impacting vulnerable groups such as individuals living with disabilities, pregnant and lactating women, the elderly, children, religious minorities, and indigenous communities. The mid-year report by the United Nations High Commissioner for Refugees [UNHCR] (2022) highlights a staggering 4.95 million refugees and asylum-seekers in the Eastern Africa region, with approximately 2.35 million originating from South Sudan.

Moreover, conflict and natural disasters have led to the displacement of 12.83 million Internally Displaced Persons (IDPs), primarily concentrated in countries like Sudan, South Sudan, Ethiopia, Somalia, and Burundi. These findings underscore the multifaceted impact of conflicts, indicating further complexities considered in this study.

II.2.5.2. Inclusion of Important Disaster Risk Factors in Selected National Action Plans

Based on the analysis of policy documents, it is evident that most concepts integrated into core policies (i.e., DRR policies, NDCs, and NAPAs) largely pertain to vulnerability and adaptive capacity variables. Notably, the crucial hazard variable of violent conflict is clearly underrepresented in these documents. Core policies of countries such as the DRC, Somalia, and South Sudan have demonstrated comparatively higher levels of inclusion of the violent conflict concept than their counterparts of very high disaster risk index such as countries like Nigeria, Chad, the CAR, Ethiopia, and Mali, which minimally incorporated the concept. Moreover, Mozambique and Niger depicted near-zero inclusion of violent conflict concepts in their core policy documents.

According to global reports, the 10 countries classified as having very high disaster risk levels, as considered in this study, exhibit varying degrees of current highly violent conflicts. Specifically, four of these countries—the CAR, the DRC, Somalia, and South Sudan—rank among the 10 least-peaceful nations, according to the Institute for Economics and Peace (IEP) (2022). Additionally, seven out of the ten countries included in this study, such as Chad, DRC, Mali, Mozambique, Niger, Nigeria, and Somalia, are among the most impacted countries by terrorism (IEP, 2022b).

Moreover, recent years have seen successful coups in Chad, Mali, and Niger alongside unsuccessful attempts in CAR. Furthermore, current interstate tensions are evident between several countries including DRC and Rwanda, Ethiopia and Sudan, Kenya and Somalia, and Sudan and South Sudan, as reported by the International Institute for Strategic Studies (2022).

The limited inclusion of violent conflict concepts within the chosen policy documents addressing disaster risk in Africa may pose challenges to effective disaster risk management, DRR and sustainable development (Keating et al., 2017). Failure to address human-induced hazards, vulnerability, and inadequate coping capacity, while attributing disasters solely to natural causes, could lead to authorities evading their responsibilities. This will perpetuate an unjust status quo where the most vulnerable populations bear the brunt of disasters repeatedly (Raju et al., 2022).

Policies geared towards effective disaster risk reduction should comprehensively address all aspects of risk, including hazards, vulnerability, and coping capacity. Inadequate coverage of (any of) these elements within policies may lead to inefficiency in tackling disaster risks, exacerbated by current and future impacts of climate change (Pilli-Sihvola & Väätäinen-Chimpuku, 2016). Therefore, it is imperative for African countries, particularly those facing medium to very high risk, to enhance the content and caliber of their DRR policy frameworks (The African Union, 2004).

II.2.6. Conclusions

This study unveils important factors that predict disaster risk in Africa and evaluates their representation within major core policies. Remarkably, among the identified drivers, only violent conflict emerged as a hazard component, while most drivers fell under lack of coping capacity, followed by vulnerability factors. Collectively, these drivers underscore the human-induced nature of disaster risks in Africa. We found a limited inclusion of concepts related to violent conflicts, but a higher inclusion of concepts linked to vulnerability in the core policies examined.

Our findings challenge prevalent assumptions within Africa's disaster risk literature. Firstly, the absence of natural hazards among the identified significant variables diverges from the traditional focus on natural hazards in the region's disaster risk discussions. Secondly, the social aspects of disaster risks, with facets of human vulnerability and inadequate coping capacity were underscored in our study. Future iterations of DRR policy frameworks must encompass these identified factors, aligning with Africa's broader developmental challenges, notably in sub-Saharan Africa.

In conclusion, comprehensive policy frameworks in addressing disaster risks, particularly in vulnerable regions such as sub-Saharan Africa are vital. Our findings emphasize that effective DRR requires policies that holistically incorporate factors of hazards, vulnerability, and coping capacity. Policies should encompass disaster drivers and regionally relevant factors that hold the key to reducing disaster risk in countries facing high or very high levels of risk. Such policies are essential to fortify resilience and advance progress towards the objectives outlined in the SFDRR and the Sustainable Development Goals of Agenda 2030. An integral aspect of revised policies should aim to alleviate poverty within the population as a means of diminishing vulnerability, enhancing coping capacity, and fostering resilience against disaster risks.

Therefore, collectively addressing all elements of risk is essential to mitigate the devastating impacts of disasters, especially in regions facing high disaster risks. Furthermore, the study highlights the need for increased attention to the inclusion of human hazards, such as violent conflicts, within DRR policies. Neglecting these human-induced risks can impede sustainable development and exacerbate the vulnerabilities of the most marginalized populations during crises. Thus, we advocate for robust, inclusive, and adaptive policy frameworks to enhance resilience and support sustainable development efforts in disaster-prone regions.

II.2.7. Limitations and Suggestions for Further Research

This study draws upon pre-existing datasets and policy documents, which, by nature, could harbor certain limitations, such as potential incompleteness or issues concerning data quality. While the findings provide valuable insights, particularly in the analysis of policy content, it is essential to note that these outcomes might not comprehensively represent the entirety of the African continent. The study focused solely on core policies from ten countries classified as having very high disaster risk indexes, potentially limiting the generalizability of the conclusions to the broader African context.

Moreover, the content analyses could be subject to limitations due to translation challenges. Some documents underwent machine translation from French to English before analysis, which might have impacted the accuracy or nuanced understanding of the content, potentially influencing our interpretations. Also, the absence of spatiotemporal assessments in this study is noteworthy. These assessments, which track changes over time and across different regions, were not incorporated. Their inclusion could have offered a more dynamic perspective, reflecting evolving circumstances and variations across various temporal and geographic contexts. However, a recent study (Eze & Siegmund, 2024) offers detailed spatiotemporal analyses using INFORM decadal data. Using decadal data, the extrapolation of disaster risk drivers for prediction is an aspect that could be explored in future research.

Despite these limitations, this research augments the comprehension of disaster risk dynamics in Africa, offering invaluable guidance for policymakers, researchers, and practitioners in the field of DRR. Given the complex interplay of environmental, socioeconomic, and conflict-driven factors contributing to disaster risk in Africa, future comprehensive case studies of at-most-risk African countries are vital. These studies should identify specific country- or community-driven risk factors, thereby shaping more tailored policy frameworks and national developmental strategies to enhance coping mechanisms and mitigate vulnerabilities toward both natural and human hazards. Further content analyses, particularly latent content analyses, would transcend keyword-based methodologies, integrating interpretation and contextualization of textual data, enriching future policy explorations.

Author Contributions
Conceptualization, **E.E.**; methodology, **E.E.**; formal analysis, **E.E.**; resources, **A.S. and E.E.**; data curation, **E.E.**; writing—original draft preparation, **E.E.**; writing—

review and editing, **E.E. and A.S.**; visualization, **E.E.**; supervision, **A.S.** All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement
Part of the data that support the findings of this study are publicly available online at https://drmkc.jrc.ec.europa.eu/inform-index/ (accessed on 15 December 2022). The list of the policies analyzed in this study and their sources are presented in the appendix Supplementary Table II.2–A1.

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Conflicts of Interest
The authors declare that there are no known competing financial interests or personal relationships that influenced the work reported in this paper.

II.2.8. Appendix A

Supplementary Table II.2–A1. List of policy documents used for content analysis.

1. Federal Democratic Republic of Ethiopia (2007). Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia. National Meteorological Agency. Pp85
2. Federal Democratic Republic of Ethiopia (2013). National Policy and Strategy on Disaster Risk Management. Addis Ababa. Pp21.
3. Federal Democratic Republic of Ethiopia (2021). Updated Nationally Determined Contribution. Pp38
4. Federal Government of Nigeria (2021). Nigeria's Nationally Determined Contribution. Federal Ministry of Environment, Abuja. Pp50
5. Federal Ministry of Environment Special Climate Change Unit (2011). National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN). Pp101
6. Federal Republic of Nigeria (2010). National Disaster Framework. Pp68 https://www.preventionweb.net/files/21708_nigherianationaldisastermanagementf.pdf. Accessed on 15 November 2022.

7. Government of Mali (2010). Plan national multi risques de preparation et de response aux catastrophes. Préparation, interventions des premiers secours, Réhabilitation et reconstruction. Pp106 https://www.preventionweb.net/publication/mali-plan-national-de-contingence-multirisques-de-preparation-et-de-reponse-aux. Accessed on 12 October 2022.
8. Government of Mozambique (2007). National Adaptation Programme of Action (NAPA). Ministry for the Co-ordination of Environmental affairs (MICOA). Pp62
9. Government of Mozambique (2021). Updated First National Determined Contribution of Mozambique. Climate Change Directorate, Ministry of Land and the Environment. 105 pp.
10. International Federation of Red Cross and Red Crescent Societies [IFRC] (2012). Plan d'organisation de secours en cas de catastrophe. pp153. https://www.ifrc.org/docs/idrl/rdc%20plan.pdf. Accessed on 12 October 2022.
11. Ministry of Humanitarian Affairs and Disaster Management [MHADM] (2018). MHADM Strategic Plan 2018—2020. Pp36
12. Republic of Mozambique (2017). Plano Director Para a Redução do Risco de desastres 2017–2030. Pp37 https://www.preventionweb.net/files/64564_planodirectorparareducaodoriscodede.pdf. Accessed on 12 October 2022.
13. Republic of Niger (2006). National Adaptation Programme of Action. Pp83
14. Republic of South Sudan (2016). National Adaptation Programme of Action (NAPA) to Climate Change. Ministry of Environment, Republic of South Sudan. Pp65
15. Republique Centrafricaine (2008). Programme d'action National d'adaptation (PANA) aux changements climatiques. Pp67
16. Republique Centrafricaine (2021). Contribution Determinee au niveau National (CDN) version revise. Ministere de L'environnement et Du Developpement Durable. Pp36
17. Republique Democratique du Congo (2006). Programme d'Action National d'Adaptation au Changement Climatique de la République Démocratique du Congo. Ministere de L'environnement. Pp94
18. Republique Democratique du Congo (2021). Contribution Déterminée à l'échelle Nationale révisée. Ministère de l'Environnement et Développement Durable Pp102
19. Republique du Mali (2007). Programme d'Action National d'Adaptation aux Changements Climatiques. Direction Nationale de la Meteorologie. Pp100

20. Republique du Niger (2021). Contribution Déterminée au Niveau Nationale. Pp30
21. Republique du Tchad (2010). Programme d'action National d'adaptation (PANA) aux changements climatiques (PANA-TCHAD). Ministère de l'Environnement, de l'Eau et des Ressources Halieutiques. Pp 63
22. Republique du Tchad (2021). Mise a Jour de la Contribution Determinee Nationale (CDN). Republique du Tchad. Pp51
23. The Federal Republic of Somalia (2013). National Adaptation Programme of Action. Ministry of National Resources. Pp93
24. The Federal Republic of Somalia (2021). Updated Nationally Determined Contribution. Pp12
25. The Republic of South Sudan (2021). South Sudan's Nationally Determined Contribution. South Sudan Ministry of Environment and Forestry, Juba. Pp163

Table II.2–A2. Inter-rater reliability measurement results.

Concepts Searched	Coded Count	Matched Coding	Percentage Match/Accuracy
Violent conflict	64	22	34.38
Uprooted people	48	44	91.67
Vulnerable Groups	62	78	125.81
Development & Deprivation	504	500	99.21
Physical infrastructure	204	139	68.14
Governance	37	39	105.41
Communication	65	68	104.62
Access to health care	19	20	105.26
Total	**1003**	**910**	**90.73**

Note: Coded count is from authors' Analyses; matched coding is from independent rater analysis.

Table II.2–A3. Disaster risk indexes and concept count results from national action plans.

Country	Central African Republic (CAR)	Chad	Congo DR	Ethiopia	Mali	Mozam-bique	Niger	Nigeria	Somalia	South Sudan
INFORM Risk Index	7.7	7.8	7.6	6.9	7	7.2	7.4	6.5	8.8	8.5
Current Highly Violent Conflict Intensity Index	8	9	9	9	9	9	9	9	10	9
DRR	NA	NA	26	3	3	0	NA	3	NA	9
NDC	0	2	2	1	NA	0	0	2	3	25
NAPA	3	3	25	0	0	1	0	8	31	19
Uprooted people Index	9.8	9.3	9.5	8.5	7.4	8.2	8	8.1	10	10
DRR	NA	NA	13	1	20	2	NA	7	NA	5
NDC	0	1	1	0	NA	2	1	2	5	4
NAPA	0	1	4	2	1	3	0	5	15	5
Vulnerable Groups Index	8.7	7.7	8.1	6.7	6.9	7.7	7.2	6.4	9.4	9.3
DRR	NA	NA	8	11	25	2	NA	1	NA	5
NDC	12	7	46	3	NA	5	1	8	5	15
NAPA	18	14	17	2	13	2	22	16	11	22
Development & Deprivation Index	10	10	8.9	9.3	9.4	9.3	10	8.2	9.7	9.7
DRR	NA	NA	82	40	108	84	NA	71	NA	82
NDC	37	104	122	61	NA	52	20	79	29	185
NAPA	144	78	90	132	122	42	112	148	110	46
Infrastructure Index	9.3	9.75	8.85	9.05	6.95	8.15	9.2	7.4	8.1	9.65

DRR	NA	NA	47	3	51	13	NA	15	NA	2
NDC	32	67	64	18	NA	39	6	30	60	42
NAPA	28	13	20	14	17	9	3	62	45	17
Governance Index	7.9	7.9	8.3	6.2	7.2	7	6.5	7.3	9	9.3
DRR	NA	NA	2	0	1	12	NA	13	NA	3
NDC	1	7	25	0	NA	0	9	3	0	19
NAPA	3	3	2	1	0	1	0	10	5	2
Communication Index	9.1	8.9	7.4	7.4	6.9	7.4	8.9	6.5	7.9	9.4
DRR	NA	NA	23	0	8	1	NA	3	NA	2
NDC	4	21	27	11	NA	9	7	19	3	81
NAPA	25	0	18	5	27	2	1	14	8	0
Access to health care Index	9.4	9.5	8	7.8	7.9	6.3	7.5	9.1	9.6	9.4
DRR	NA	NA	19	0	8	0	NA	1	NA	0
NDC	0	0	0	0	NA	1	0	1	0	3
NAPA	2	0	3	0	3	0	1	11	7	0

Note: DRR = Disaster Risk Reduction policies; NDC = Nationally Determined Contribution; NAPA = National Adaptation Programme of Action

II.2.9. References

Annan, N. (2014). Violent conflicts and civil strife in West Africa: Causes, challenges and prospects. *Stability: International Journal of Security and Development*, 3(1), 1-16. https://doi.org/http://doi.org/10.5334/sta.da

Bello, O., Bustamante, A., & Pizarro, P. (2021). *Planning for disaster risk reduction within the framework of the 2030 Agenda for Sustainable Development.* https://repositorio.cepal.org/bitstream/handle/11362/46639/1/S2000452_en.pdf

Bhavnani, R., Vordzorgbe, S., Owor, M., & Bousquet, F. (2008). *Report on the status of disaster risk reduction in the Sub-Saharan Africa region.* Commission of the African Union, World Bank, UNISDR, Nairobi. http://lib.riskreductionafrica.org/bitstream/handle/123456789/579/report%20on%20the%20status%20of%20disaster%20risk%20reduction%20in%20the%20sub-saharan%20africa%20region.pdf?sequence=1

Birkmann, J., & Welle, T. (2016). The WorldRiskIndex 2016: Reveals the necessity for regional cooperation in vulnerability reduction. *Journal of Extreme Events,* 3(02), 1650005. https://doi.org/10.1142/S2345737616500056

Birkmann, J., Jamshed, A., McMillan, J. M., Feldmeyer, D., Totin, E., Solecki, W., ... & Alegría, A. (2022). Understanding human vulnerability to climate change: A global perspective on index validation for adaptation planning. *Science of The Total Environment*, *803*, 150065. https://doi.org/10.1016/j.scitotenv.2021.150065

Breiman, L. (2001). Random Forests. *Machine Learning*, 45(1), 5-32. https://doi.org/10.1023/A:1010933404324

Burke, M., Hsiang, S. M., & Miguel, E. (2020). *Historical and future influence of climate on human violence.* AGU Fall Meeting Abstracts. Online everywhere, 1–17 December 2020. pp. GH019–002

Cappelli, F., Costantini, V., Paglialunga, E., Sforna, G., & Markandya, A. (2022). The Climate–Conflicts Nexus and the Role of Geographical Spillovers. In Climate and Development (pp. 221-255). World Scientific. https://doi.org/10.1142/9789811240553_0008

Egawa, S., Jibiki, Y., Sasaki, D., Ono, Y., Nakamura, Y., Suda, T., & Sasaki, H. (2018). The correlation between life expectancy and disaster risk. *Journal of Disaster Research*, 13(6), 1049-1061. https://doi.org/10.20965/jdr.2018.p1049

Eze, E., & Siegmund, A. (2023). *Disaster risk factors and spatiotemporal trends in Africa*. EGU General Assembly 2023, Vienna, Austria, 24–28 April 2023, EGU23-8307. https://doi.org/10.5194/egusphere-egu23-8307

Eze, E., & Siegmund, A. (2024). Identifying disaster risk factors and hotspots in Africa from spatiotemporal decadal analyses using INFORM data for risk reduction and sustainable development. *Sustainable Development*, 1-22. https://doi.org/10.1002/sd.2886

Global Peace Index 2022: *Measuring Peace in a Complex World*. (2022). Institute for Economics and Peace (IEP). Retrieved December 22 from https://www.visionofhumanity.org/public-release-data/

Global Terrorism Index 2022: *Measuring the Impact of Terrorism*. (2022). Institute for Economics and Peace (IEP) Retrieved December 22 from https://www.visionofhumanity.org/public-release-data/

Hoch, J. M., de Bruin, S. P., Buhaug, H., Von Uexkull, N., van Beek, R., & Wanders, N. (2021). Projecting armed conflict risk in Africa towards 2050 along the SSP-RCP scenarios: a machine learning approach. *Environmental Research Letters*, 16(12), 124068. https://doi.org/10.1088/1748-9326/ac3db2

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative health research*, 15(9), 1277-1288. https://doi.org/10.1177/1049732305276687

Imperiale, A. J., & Vanclay, F. (2021). Conceptualizing community resilience and the social dimensions of risk to overcome barriers to disaster risk reduction and sustainable development. *Sustainable Development*, 29(5), 891-905. https://doi.org/10.1002/sd.2182

International Institute for Strategic Studies (2022). *The Armed Conflict Survey 2022: Sub-Saharan Africa Regional Analysis*. Retrieved December 22, 2022, from https://www.iiss.org/blogs/analysis/2022/11/acs-2022-sub-saharan-africa#:~:text=Adding%20complexity%2C%20inter-state%20disputes,and%20Sudan%20and%20South%20Sudan.

Keating, A., Campbell, K., Mechler, R., Magnuszewski, P., Mochizuki, J., Liu, W., Szoenyi, M., & McQuistan, C. (2017). Disaster resilience: what it is and how it can engender a meaningful change in development policy. *Development Policy Review*, 35(1), 65-91. https://doi.org/10.1111/dpr.12201

Kimengsi, J. N., & Mbih, R. A. (2022). International Disaster Risk Management Policies and Instruments: A Review. In R. A. Balgah & J. N. Kimengsi (Eds.), *Disaster Management in Sub-Saharan Africa: Policies, Institutions and Processes* (pp. 35-56). Emerald Publishing Limited, Bingley. https://doi.org/10.1108/978-1-80262-817-320221002

Levi, S. (2021). Country-level conditions like prosperity, democracy, and regulatory culture predict individual climate change belief. *Communications Earth & Environment*, 2(1), 51. https://doi.org/10.1038/s43247-021-00118-6

Manyena, B. (2016). After Sendai: Is Africa bouncing back or bouncing forward from disasters? *International Journal of Disaster Risk Science*, 7, 41-53. https://doi.org/10.1007/s13753-016-0084-7

Marin-Ferrer, M., Vernaccini, L., & Poljansek, K. (2017). *Index for Risk Management (INFORM) Concept and Methodology Report—Version 2017* (EUR 28655). doi:10.2760/094023.

Masson-Delmotte, V. (2018). *Global Warming of 1.5 °C: An IPCC Special Report on Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Contex of Strengthening the Global Response to the Thereat of Blimate Change, Sustainable Development, and Efforts to Eradicate Poverty*; Cambridge University Press: Cambridge, UK, 2018.

McHugh, M. L. (2012). Interrater reliability: the kappa statistic. *Biochemia medica*, (Zagreb) 22(3), 276-282. https://www.ncbi.nlm.nih.gov/pubmed/23092060

Nicodemus, N., & Dennis, O. (2021). Achieving Sendai Framework in Africa: Progress and challenges toward Target E. *Natural Hazards and Earth System Sciences Discussions*, 1-20. https://doi.org/10.5194/nhess-2021-132

Okunlola, O. C., & Okafor, I. G. (2022). Conflict–poverty relationship in Africa: a disaggregated approach. *Journal of Interdisciplinary Economics*, 34(1), 104-129. https://doi.org/10.1177/0260107920935726

Paluszynska, A. (2017). *Structure mining and knowledge extraction from random forest with applications to the cancer genome atlas project*. University of Warsaw Master Thesis.

Paluszynska, A., Biecek, P., and Jiang, Y. (2020). *Explaining and visualizing random forests in terms of variable importance.* R package version 0.10.1, https://github.com/ModelOriented/randomForestExplainer. Last accessed on 22 December 2022

Paul, N., Silva, V., & Amo-Oduro, D. (2022). Development of a uniform exposure model for the African continent for use in disaster risk assessment. *International Journal of Disaster Risk Reduction*, 71, 102823. https://doi.org/10.1016/j.ijdrr.2022.102823

Pilli-Sihvola, K., & Väätäinen-Chimpuku, S. (2016). Defining climate change adaptation and disaster risk reduction policy integration: Evidence and recommendations from Zambia. *International Journal of Disaster Risk Reduction*, 19, 461-473. https://doi.org/10.1016/j.ijdrr.2016.07.010

Raju, E., Boyd, E., & Otto, F. (2022). Stop blaming the climate for disasters. *Communications Earth & Environment*, 3(1). https://doi.org/10.1038/s43247-021-00332-2

Strategic Country Cluster Evaluation (SCCE): *Sahel and Sudan-Guinea Savanna biomes.* (2021). Global Environment Facility. Retrieved January 15, 2024 from https://www.gefieo.org/evaluations/scce-biomes

The African Union (2004). Africa regional strategy for disaster risk reduction. Disaster Risk Reduction for Sustainable Development in Africa.

https://www.unisdr.org/files/13093_AFRICAREGIONALDRRSTRATEGYfullPDF.pdf

Tiepolo, M., & Braccio, S. (2020). Mainstreaming disaster risk reduction into local development plans for rural tropical Africa: A systematic assessment. *Sustainability*, 12(6), 2196. https://doi.org/10.3390/su12062196

United Nations High Commission for Refugees (UNHCR). (2022) *East and Horn of Africa, and the Great Lakes Region Operational Update (April–June 2022)*; UNHCR: Geneva, Switzerland. https://data.unhcr.org/en/documents/details/94478

United Nations nternational Strategy for Disaster Reduction (UNISDR), (2015). *Sendai framework for disaster risk reduction 2015–2030.* UNISDR: Geneva, Switzerland, p.32. Retrieved from https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030/

Van Niekerk, D. (2015). Disaster risk governance in Africa: A retrospective assessment of progress against the Hyogo Framework for Action (2000-2012). *Disaster Prevention and Management*, 24(3), 397-416. https://doi.org/10.1108/DPM-08-2014-0168

van Niekerk, D., Coetzee, C., & Nemakonde, L. (2020). Implementing the Sendai Framework in Africa: Progress against the targets (2015–2018). *International Journal of Disaster Risk Science*, 11, 179-189. https://doi.org/10.1007/s13753-020-00266-x

Van Weezel, S. (2020). Local warming and violent armed conflict in Africa. *World Development*, 126, 104708. https://doi.org/10.1016/j.worlddev.2019.104708

Vlachogiannis, D., Sfetsos, A., Markantonis, I., Politi, N., Karozis, S., & Gounaris, N. (2022). Quantifying the Occurrence of Multi-Hazards Due to Climate Change. *Applied Sciences*, 12(3), 1218. https://doi.org/10.3390/app12031218

Welle, T., & Birkmann, J. (2015). The world risk index–an approach to assess risk and vulnerability on a global scale. *Journal of Extreme Events*, 2(01), 1550003. https://doi.org/10.1142/S2345737615500037

Witmer, F. D., Linke, A. M., O'Loughlin, J., Gettelman, A., & Laing, A. (2017). Subnational violent conflict forecasts for sub-Saharan Africa, 2015–65, using climate-sensitive models. *Journal of Peace Research*, 54(2), 175-192. https://doi.org/10.1177/0022343316682064

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Data Curation	✓		
Writing-Original Draft	✓		
Writing-Review&Editing	✓	✓	
Visualization	✓		
Supervision		✓	
Project administration	✓	✓	
Funding acquisition	✓		

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Alexander Siegmund		29.07.2024

3

"By failing to prepare, you are preparing to fail." ~ Benjamin Franklin

II.3. Next-generation core competency gaps for disaster risk management and preparedness in UNESCO-designated heritage sites

Abstract

Heritage plays a critical role in sustainability. The absence of studies examining core competencies among UNESCO actors for disaster risk management (DRM) and preparedness in heritage sites prompted this survey. Respondents from 59 countries revealed a high rating of all listed competencies with significant discrepancies concerning relationship-building requiring attention. Additionally, substantial variations in competencies were linked to factors such as age, job positions, and previous experiences with disaster damages. Holistic DRM proficiency is the primary predictor of disaster preparedness within heritage sites. Thus, enhancing preparedness through experiential learning and coordinated knowledge-sharing mechanisms will preserve our collective heritage for sustainable futures.

Keywords: Disaster preparedness; disaster risk Management; heritage conservation; next-generation core competencies; sustainable futures; UNESCO sites

Highlights

- UNESCO site actors exhibit high proficiency in DRM next-generation core competencies
- Respondents' job position and age are significant variables of DRM competencies
- Damages during past disasters influenced levels of DRM competencies
- Holistic DRM proficiency is a significant predictor of site disaster preparedness
- Competent UNESCO actors are key to heritage conservation for sustainable futures

II.3.1. Introduction

Heritage, encompassing tangible and intangible aspects, plays a transformative role in nurturing sustainable futures. Physical artefacts and built heritage are sometimes more prominent in the discourse but Botta (2017) emphasises the inclusion of intangible heritage in the process of future making. Moreover, engaging with the past is recognised by Sandford (2019) as integral to crafting future trajectories due to the deeper insights and participatory approaches that are gained. Specifically, a recent study by Bassily et al. Bassily et al. (2023) emphasizes how built heritage contributes to local resilience and sustainability in various heritage sites by fostering strong place attachment and socioeconomic activities.

Also, the significance of heritage in guaranteeing sustainable futures is widely acknowledged. Trillo et al. (2020) explain such consensus as primarily owing to the far-reaching effects of heritage on various domains such as political aspects, ethical contemplation, and the development of local economies. In addition, sustainability, considered both a goal and a means, demands professionals attuned to its transformative potential (Janhonen-Abruquah et al., 2018). Hence, we consider professionals such as actors responsible for managing heritage sites that link us to the past, which must be preserved for future generations as an essential component in forging sustainable futures. Consequently, the focus of this study centres on exploring the disaster risk management (DRM) competencies of the professionals involved with overseeing UNESCO-designated heritage sites globally.

Three distinct categories of sites, each bearing exceptional natural or cultural significance are recognised by UNESCO: Global Geoparks (GGs), Biosphere Reserves (BRs), and World Heritage Properties (WHPs). While GGs stand as guardians of unique geological wonders, BRs are cradles of biodiversity conservation landscapes, and WHPs hold historical and cultural treasures of universal importance (Pavlova et al., 2019). As of October 2023, these UNESCO-designated treasures span the globe with 195 GGs, 748 BRs, and 1,199 WHPs, sited within 48, 168, and 134 countries, respectively.

Beyond being seeming passive repositories of nature and history, these UNESCO sites (GGs, BRs and WHPs) support sustainable development by intentional conservation and preservation of nature to provide the present generation, with a glimpse of the past and retain the same for those yet unborn. The contributions of these sites have also been connected to the improvement of the quality of life (De Silva, 2003); and the advancement of multi-level initiatives socially, economically, and environmentally (Luo et al., 2022). Hence, significant losses of these sites would not only strip its beneficiaries of their natural and cultural legacies but threaten Agenda 2030, which the United Nations set out as an action for people, the planet and prosperity.

Currently, a disconcerting reality emerges as UNESCO-designated sites are facing threats by increasing disasters. Pavlova et al. (2017) and Pavlova et al. (2021) indicate that over 2,000 UNESCO sites are exposed to an array of natural hazards. Moreover, the analysis of threats to heritage sites by UNESCO (2015) encompasses a wide range of potential dangers, including buildings and development, transportation and services infrastructure, pollution, biological resource use and modification, physical resource extraction, temperature changes, rain, dust, visitor pressure, illegal activities, climate change, severe weather events, geological events, and invasive or alien species. Drawing from several studies, Falk and Hagsten (2023) highlight both human and natural threats to heritage sites. These threats include climate change, drought, heavy rains, geological hazards such as earthquakes, volcanic eruptions, avalanches, landslides, extreme weather, storms, wildfires, sea level rise, air pollution, acid rain, over-tourism, crowding, urbanization, war, terrorism, conflicts, and vandalism.

While the impacts of natural hazards on heritage sites are severe, threats such as air pollution, which causes deterioration and corrosion Spezzano (2021) and urbanization, which impacts historical skylines (Ashrafi et al., 2021), along with the pressure of over-tourism identified by Frey and Briviba (2020), can be more insidious and gradual. Furthermore, the intensification in both the frequency and potency of human and nature-induced hazards compounds the challenge, making them increasingly unpredictable. In recognition that the occurrence of natural hazards, including their frequency and intensity, remains beyond our control, our focal point in this study shifts towards proactive measures that mitigate hazards' impact when they inevitably strike. It is within this context that the current study assumes its critical role, focusing on the assessment of DRM competencies held by UNESCO site managers and their dedicated staff.

Whereas Eze and Siegmund (2024a) identified competency gaps among UNESCO actors in the application of innovative disaster risk reduction (DRR) technologies and approaches, their study focused only on a specific aspect of competency. They emphasized the need for a comprehensive investigation into the broader scope of DRM competencies possessed by UNESCO actors. Such an in-depth examination is crucial for designing tailored professional development programs that address all necessary competencies for effective DRM. This current study aims to fill this gap by providing a holistic assessment of DRM competencies among UNESCO site actors, ensuring a more robust foundation for developing targeted training and capacity-building initiatives.

II.3.1.1. Disaster risk management (DRM) in UNESCO sites

According to the United Nations General Assembly [UNGA] (UNGA, 2016), DRM entails the implementation of DRR policies and strategies with the primary objectives of forestalling the emergence of new disaster risks, reducing the existing disaster risks, and effectively handling any residual risks. These actions are expected to be guided by the Sendai Framework for Disaster Risk Reduction of the United Nations International Strategy for Disaster Reduction (UNISDR, 2015), link sustainable development and climate change adaptation, and could take prospective, corrective, compensatory, community-based, or local and indigenous peoples' approaches (UNGA, 2016). Therefore, DRM is anticipated to enhance resilience and result in a significant decrease in disaster-related losses within UNESCO sites.

Recent studies have undertaken inquiry into different aspects of DRM with a focus on UNESCO-designated sites. Durrant et al. (2023) found that WHP managers neither had sufficient access to DRM strategies nor practical experience in DRM implementation. Their study was, however, delimited to risk perception. Furthermore, the study of Minguez Garcia (2020) provides a strong connection between DRM and cultural heritage preservation, with advocacy for international collaboration for knowledge exchange such as sharing of good practices and learning experiences.

The Emergency Preparedness and Response Unit of UNESCO is actively involved in improving the prospect of DRM in designated sites in addition to other associated international organisations such as the International Scientific Committee for Risk Preparedness (ICOMOS-ICORP), and the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM). Both ICOMOS-ICORP and ICCROM foster DRM, disaster preparedness and cultural heritage protection from natural and human disasters by providing education, training, research, advocacy, and information dissemination services to WHPs.

These organisations have produced comprehensive documents and reading resources related to DRM in UNESCO sites (Pedersoli Jr et al., 2016; UNESCO & ICCROM, 2016; UNESCO, 2010). While it is anticipated that UNESCO site actors, including managers and staff, possess significant DRM knowledge, a thematic survey report by Pavlova et al. (2019) reveals a deficiency in risk assessment and management plans within numerous BRs and GGs. Surprisingly, the assessment of DRM competencies possessed by UNESCO site actors has received limited, if any, attention thus far. Hence, this study marks the initial step towards addressing this critical gap.

II.3.1.2. Disaster risk management core competencies

There is no universally accepted definition for the term competency. An earlier definition by Strebler (1997) presents competency as either a set of behaviours that individuals need to exhibit or as minimum performance standards. However, the concept has continued to evolve. Hoffmann (1999) outlines three primary viewpoints found in the literature regarding the definition of competency – as an individual's observable performance, the standard or quality of the outcomes resulting from their performance, or the inherent attributes of the individual. Some studies tend to combine at least two of these viewpoints. For example, the definition of Wong (2020), and Pharaoh and Visser (2023) regard competency as a set of observable and measurable attributes or success factors individuals require for effective performance at work.

The diverse meanings of the concept of competency emphasize the necessity of clarifying its usage intentions (Hoffmann, 1999). Therefore, we clarify that in this study, we adopt the term competency to incorporate two of the three viewpoints identified by Hoffmann (1999) – respondents' inherent attributes and their performance regarding DRM. Hence, competency is considered as UNESCO site actors' internal DRM attributes and job performance. Specific attention is given to core competencies. Core competencies refer to shared learning experiences that integrate various skills and focus on strategies unifying members of an organisation (Feldmann-Jensen et al., 2019). Aside from helping to frame research, core competencies are useful for setting performance standards, development of job descriptions and learning outcomes for educational programmes, candidate selection and performance evaluation (Feldmann-Jensen et al., 2019).

This study extends the output of Feldmann-Jensen et al. (2019) Through a systematic four-step process, they devised a comprehensive framework comprising 13 core competencies nested within three categories and their corresponding measurements, to address environmental challenges and bolster community resilience in an era of high turbulence, uncertainty, and complexity (Figure 1). Termed the Next Generation Core Competencies, this framework is designed to meet the demands of the dynamic environmental landscape beyond 2030. Hence, conducting a study to evaluate the proficiency of UNESCO site actors in these competencies represents a substantial and pioneering contribution to heritage conservation. This inquiry, which evaluated 31 out of the total 58 measures of the DRM core competencies (Figure II.3–1), not only breaks new ground but also holds futuristic implications for the sustainability of UNESCO sites, extending the achievement of sustainable futures beyond the scope of global policies like Agenda 2030 and SFDRR.

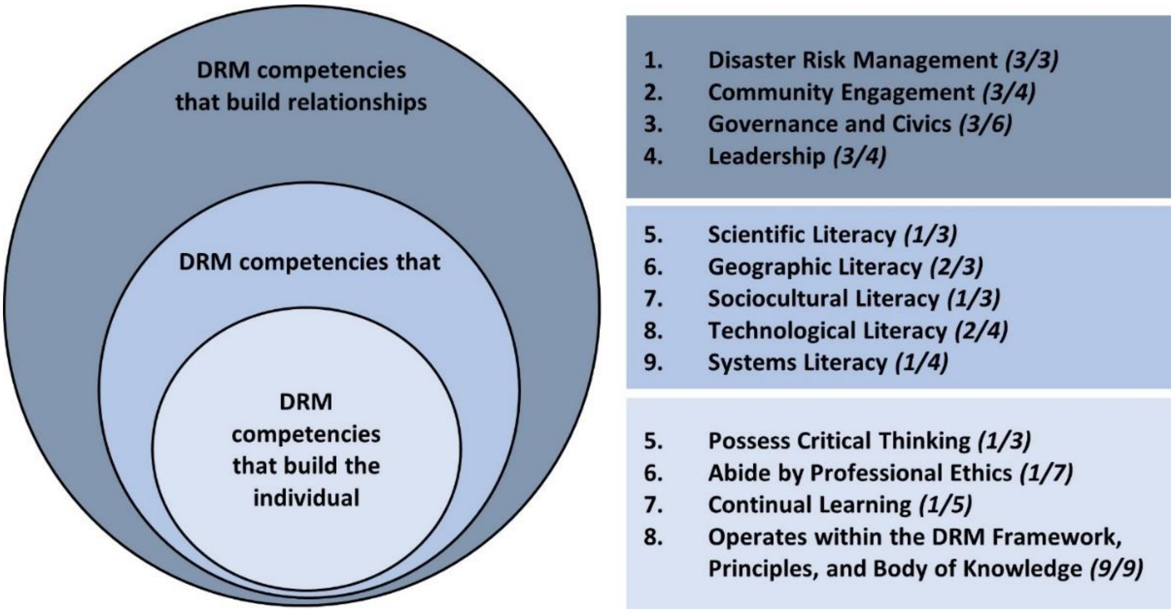

Figure II.3–1: Nested relationship of next-generation DRM core competencies tested in this study. The numbers in parentheses indicate the chosen number out of the total available measures for each competency.
Adapted from Feldmann-Jensen et al. (2019)

II.3.1.3. Disaster preparedness

The term disaster preparedness is defined by UNISDR (2009) as the sum of knowledge and capabilities developed in anticipation of disasters to effectively respond to and recover from their impacts. Furthermore, UNISDR (2009) describes disaster preparedness to include aspects such as contingency planning, coordination, evacuation procedures, dissemination of public information, simulations, and the stockpiling of equipment. Recent research, exemplified by Nikkanen et al. (2023), presents numerous factors influencing preparedness, including personal attributes, socioeconomic conditions, risk perception, and prior experiences with disasters. Moreover, Eze and Siegmund (2024b) identified disaster awareness and resource availability as significant predictors of disaster preparedness at UNESCO-designated sites.

Aligned with these identified factors, this research endeavours to assess the disaster preparedness of UNESCO site actors by scrutinizing their expression of next-generation core competencies regarding DRM. These professionals play a crucial role in DRM implementation and the facilitation of disaster preparedness within these sites. Sutton and Tierney (2006) notably emphasize the indispensable nature of human resources as pivotal assets essential for effective DRM and preparedness efforts. Evaluating the DRM competencies of UNESCO actors and correlating these with the disaster preparedness of their respective sites remains an unexplored domain in existing literature, particularly concerning factors akin to those highlighted by Nikkanen et al. (2023). Factors such as age, gender, educational attainment, length of service, household income adequacy, UNESCO site classification, site location, past disaster consequences, and the extent of damages incurred from previous disasters are meticulously examined in this study.

II.3.1.4. Aims and objectives of this study

This study records the first known efforts to unveil the levels of DRM next-generation core competencies possessed by UNESCO site actors and relate the same to site disaster preparedness. It provides an overview of the inherent attributes of respondents and their performance concerning DRM in UNESCO sites. Beyond providing a state-of-the-art on the subject, the study provides crucial aspects of focus for performance evaluation and future-oriented training development. The overarching question of the study is 'What DRM core competencies are held by UNESCO site actors and how do these competencies relate to disaster preparedness of UNESCO sites?'

Our specific objectives seek to answer four research questions:

1. What are the levels of DRM next-generation core competencies possessed by UNESCO site actors?
2. How do demographic factors, disaster exposure, disaster consequences, and participation in training programs influence ratings of DRM next-generation core competencies among UNESCO site actors?
3. What are the dimensions of DRM next-generation core competencies among UNESCO site actors?
4. What is the relationship between expressed DRM next-generation core competencies by UNESCO site actors and disaster preparedness in UNESCO sites?

II.3.2. Methods

II.3.2.1. Design

This research adopted a descriptive survey methodology, as described by Kothari (2004), which aims to illustrate the current situation among selected participants using specific variables. This design was selected as it conforms to the aim of this study, which investigated the levels of DRM next-generation core competencies possessed by UNESCO site actors in association with the levels of disaster preparedness of UNESCO sites. Moreover, Eze et al. (2022) describe survey results as essential for information-gathering for designing tailor-made professional development programs.

In this study, responses collected using an adapted questionnaire were analyzed to assess the next-generation DRM core competencies held by UNESCO site actors and the emergency preparedness of their sites. The core competencies were evaluated using a 7-point Likert-type scale with 31 items, ranging from strongly disagree (1) to strongly agree (7), based on the competencies designed by Feldmann-Jensen et al. (Feldmann-Jensen et al., 2019) and illustrated in Figure 1. In addition, the preparedness items required respondents to answer with 'Yes', 'No', or 'Not applicable'. Additional questions focused on the demographic characteristics of the respondents, allowing them to select their preferred responses from predefined options. The questionnaire is herewith attached as Supplementary Material S1.

II.3.2.2. Participants sampling and data collection procedures

Data was collected for this study through an online survey distributed through Survey Monkey to 1,009 email addresses of UNESCO actors globally. These actors are site staff, site managers, staff of UNESCO national commissions, and focal persons on UNESCO sites who are trained and charged with overseeing our collective heritage. The demographic information of respondents is provided as Supplementary Material S2.

Given the clear definition of the intended target respondents as actors within UNESCO-designated sites, this study utilized two convenience non-probability sampling methods: harvested email lists and river sampling. The harvested email list method, according to Fricker (2008), involves extracting email addresses from online sources, while the river sampling technique described by Lehdonvirta et al. (2021) entails sending targeted invitations to the study via clickable links directed at a preselected population.

The questionnaire was distributed in two phases, spanning from August 2022 to February 2023 and then from September to October 2023. This double circulation aimed to boost response numbers with reminders sent during both phases. Three reminder emails were dispatched in October 2022, November 2022, and February 2023 during the first phase, while two reminders were issued in the second phase after the fourth and fifth weeks following the relaunch. Despite these efforts, only 141 responses were gathered, resulting in a response rate of 13.98%. However, the received responses represented around 55 countries, encompassing diverse sites, continents, and contexts.

Although the responses might lack representativeness due to the limited number, they are still valuable for offering an initial exploration into the DRM next-generation core competencies held by responding UNESCO actors. In personal communication with a UNESCO headquarters staff member, the low participation was attributed to their hectic schedules. Additionally, Pharaoh and Visser (2023) explain that survey fatigue and a tendency to receive numerous surveys might contribute to the reluctance to respond to surveys that prospective respondents considered 'non-essential'.

II.3.2.3. Data collection instrument development and testing

Before this research, no prior survey known to the authors had assessed the DRM core competencies of UNESCO actors using a similar questionnaire sourced from Feldmann-Jensen et al. (2019), detailing the next-generation DRM core competencies. Concurrently, the 10 items on emergency site preparations were extracted from UNESCO, ICOMOS & IUCN (2010). In developing the main section of the questionnaire, priority was given to items related to relevant frameworks, principles, and literature covering DRM core competencies. These competencies aim to develop the UNESCO actor as an individual, a practitioner, and within work-community relationships. Purposeful selections were made from all 13 core competencies outlined by Feldmann-Jensen et al. (2019) as depicted in Figure II.3–1.

To ensure the questionnaire's validity and reliability, two meticulous steps were undertaken. Initially, the designed questionnaire underwent rigorous face validity assessment. Two Professors and (post)doctoral researchers from the Department of Geography at Heidelberg University of Education were consulted to scrutinize the questionnaire items regarding relevance, clarity, and alignment with the research objectives. The feedback received from six validators, including a professor, was meticulously reviewed, and incorporated into the final version. Based on their suggestions, certain items were omitted to streamline the questionnaire.

Additionally, the final version underwent machine translation from English into various UNESCO languages (Arabic, Chinese, French, Portuguese, Russian, and Spanish) and was carefully scrutinised by native speakers before distribution. Subsequently, a pilot study was conducted among selected respondents in European UNESCO sites, yielding 41 responses. An assessment of the internal consistency of the DRM next-generation core competency items using Cronbach's Alpha resulted in a remarkable figure of .976, indicating an exceptionally high level of internal consistency (> 97%) among the questionnaire items. Following the analysis of the complete set of responses (n =141), the reliability measure yielded .974, further affirming the questionnaire's reliability and consistency across the sample.

II.3.2.4. Data analyses

The collected survey responses were analysed using the IBM SPSS Statistics (Version 29). Descriptive statistics were used for respondents' characteristics, levels of expressed DRM next-generation core competencies, site disaster preparedness, and cluster characteristics. To interpret the output of the mean ratings of the DRM next-generation core competencies, we designated X ¯ = ≥ 4.0 to indicate a high rating. Independent t-test and analysis of variance (ANOVA) were conducted to determine the differences in mean DRM next-generation competencies ratings based on respondent characteristics. Correlation tests provided insights into the association among the groups of competencies in Figure 1 (i.e., competencies that build the individual, practitioner, and relationships).

Furthermore, for dimension reduction, we employed the Principal Component Analysis (PCA). The PCA is a mathematical method used to condense complex data into a smaller set of uncorrelated dimensions known as principal components (PCs) and is applicable in various scientific fields (Joliffe, 2002). One of the key strengths of PCA lies in its non-parametric nature, allowing it to be a robust and versatile tool for data analysis without reliance on specific distribution assumptions (Elhaik, 2022). According to Eze and Nwagu (2021), PCs are typically considered significant if they have Eigenvalues of 1.00 or higher.

In this study, the PCA was used to reduce the dimensionality of the DRM core competencies to effectively identify their key components as rated by respondents. In this way a simple presentation of the complexity of the competency items is easily categorised and presented to readers, retaining the most significant information, while enhancing the interpretability of the results. The PCA analysis was conducted using IBM SPSS Statistics (Version 29), employing varimax rotation with Kaiser normalization. Before conducting PCA analyses, the collected data underwent an assessment to ensure suitability for factor analysis. The Kaiser-Meyer-Olkin (KMO) value, which was calculated to be .908, surpassed the recommended threshold of .60 as proposed by Kaiser (1974). Additionally, Bartlett's test of sphericity yielded a significant value of (.000), affirming the factorability of the data.

To identify the grouping of disaster preparedness based on DRM next-generation core competency ratings, cluster analyses were implemented. Cluster analysis is a method aimed at categorizing similar data into distinct clusters without overlaps, with robust clustering techniques serving various purposes, including anomaly detection, improved data comprehension, hypothesis formulation, recognition of similarity patterns among instances, data compression, and more (Kaufman & Rousseeuw, 2009; Jain, 2010). Among the clustering algorithms, Reddy and Vinzamuri (2018) opine that partitional and hierarchical clustering stand out for their simplicity and widespread use.

In this study, a partitional clustering approach was utilized to classify observations into k clusters, employing the criterion function of minimizing the distance between points within each cluster. This technique was chosen to enhance the understanding of the dataset and unveil patterns of DRM next-generation core competencies of UNESCO actors and the disaster preparedness of their sites. Firstly, a two-step cluster analysis was performed to unveil the optimum number of clusters for the data. This was followed by a k-means cluster analysis to classify the data into the number of clusters previously obtained in the first step. Variables used for the cluster analyses include the mean ratings of items in the identified principal components and the disaster preparedness responses.

II.3.2.5. Ethical considerations

The questionnaire used in this study received approval from the Department of Geography at Heidelberg University of Education following a comprehensive self-administered ethical review that determined no potential harm to respondents. This review allowed the study to proceed without the need for a voting process within the ethical committee. Consequently, the study strictly adhered to established scientific practices, encompassing elements such as informed consent, maintaining anonymity of responses, ensuring data privacy, and upholding participants' rights to withdraw from the study at any point, aligning with ethical codes including those outlined by the American Psychological Association (APA) (APA, 2016). Throughout the study, five individuals chose to withdraw voluntarily.

II.3.3. Results

II.3.3.1. Levels of expressed DRM next-generation core competencies

A total of 83 responses were fully completed and used for the analyses. Most respondents agree with all the listed item statements on DRM next-generation core competencies that build the individual, practitioner, and relationships, with a cluster mean of 5.17 (Table II.3–1). An individual-building competency item related to the demonstration of professional ethics had the highest mean responses ($\bar{X}$ = 6.05), while a relationship-building item about access analyses of power, policy and legal parameters related to disaster risk issues ($\bar{X}$ = 4.47) was the least.

Whereas the overall mean of DRM next-generation core competencies of the respondents is $\bar{X}$ = 5.17, the practitioner-building competency items had the highest mean responses of the three categories ($\bar{X}$ = 5.32). The individual-building and relationship-building competencies had a mean response of $\bar{X}$ = 5.26 and $\bar{X}$ = 4.91 respectively. Therefore, there is a positive perception regarding all categories of the listed DRM competencies. However, emphasis may be needed on developing relationship-building competencies to ensure a holistic approach to disaster risk management.

Table II.3–1: Results of UNESCO actors rating in the listed DRM next-generation core competencies

DRM next-generation core competency items	Mean	Std. Deviation
I possess critical thinking for problem identification and solutions	5.66	1.28
I demonstrate Professional ethics of respect, justice, integrity, and selfless service	6.05	1.13
I engage in continual learning and knowledge expansion	5.92	1.14
I consider all hazards, phases, stakeholders, and impacts relevant to disasters	5.30	1.48
I expect future disasters and develop disaster-resistant and disaster-resilient communities	5.14	1.63
I utilize sound risk management principles in assigning priorities and resources	4.59	1.49
I ensure unity of efforts among all community members to manage disaster risk	4.94	1.43
I create and sustain a team atmosphere to facilitate communication	5.52	1.39
I facilitate synchronous activities among all relevant stakeholders to achieve a common purpose	5.34	1.37
I use creative and innovative approaches to solving disaster challenges	4.96	1.47
I value a science and knowledge-based approach for continuous improvement	5.82	1.21
I consider, utilize, and value the growing body of disaster risk management literature for building disaster-resilient communities	5.08	1.50
I appreciate scientific processes and how their applications benefit humanity	5.89	1.30
The world is made of physical, built, and social systems, which interact in multifaceted ways, producing varying levels of risk and vulnerability	5.76	1.14
People and places are connected in a dynamic network of global relationships	5.73	1.28
I help others understand the relationship between social factors and disaster risk concentration	5.14	1.40
I use existing appropriate technologies in disaster risk management practice	4.55	1.70

I consider ethical, legal, and social implications when determining the appropriateness of a technology application for disaster risk management	4.84	1.73
I work in partnership with others and utilize a range of resources available within the system to establish an innovative solution to a pressing problem	5.33	1.52
I clearly communicate and explain hazard risks to a wide range of stakeholders	5.01	1.58
I understand and apply disaster risk management frameworks to identify and manage risks	4.84	1.57
I monitor, evaluate, and review risk management processes and outcomes	4.77	1.56
I involve the stakeholders to focus on the disaster risk exposure	4.93	1.56
I facilitate a community learning process through communication, dialogue, negotiation, and cooperation	5.25	1.46
I support community networks through the ongoing improvement of collective disaster risk reduction goals and interventions	4.81	1.56
I identify and analyse a hazard risk issue for action	4.73	1.53
I analyse access to the relational dynamics of, and the ramifications from those in positions of political power, policy, and legal parameters in connection to disaster risk issues	4.47	1.56
I bring people together across sectors to identify and address disaster risk issues at hand	4.66	1.70
I inspire a shared vision with community stakeholders and involve them to contribute to its achievement	4.98	1.57
I empower my staff to successfully pursue our organisation's vision	5.22	1.63
I resolve conflicts that emerge within or between the organization and the community it serves	5.16	1.55
Cluster mean	**5.17**	

n = 83

II.3.3.2. Factors influencing possession of DRM next-generation core competencies

Ratings of possession of DRM next-generation core competencies by staff members of UNESCO commissions and other focal persons were significantly the highest, while the site staff had the lowest ratings of individual, practitioner, relationship, and overall DRM core competencies ($p = .011$, $.012$, $.006$, and $.006$ respectively). Respondents aged 55 to 64 years had significantly higher ratings than their counterparts of other age groups in the individual, practitioner, relationship, and overall DRM core competencies ($p = .018$, $.031$, $.010$, and $.011$ respectively).

Respondents who recorded the highest consequences of disasters also had significantly highest ratings of individual, practitioner, relationship, and overall DRM core competencies ($p =.021$, $.061$, $.013$ and $.019$ respectively). Furthermore, all DRM competency components (i.e., individual, practitioner and relationship) were very highly significantly associated with the overall competency score ($r > .940^{**}$).

In summary, there is a noticeable gap in rated competencies at the site level compared to higher administrative levels. Additionally, older respondents and those with more disaster experience among UNESCO actors show enhanced competencies. The strong correlation between individual competency components and overall competency ratings suggests that improving one area of competency could positively influence the overall DRM competence of UNESCO actors.

Table II.3–2: Results of significant difference tests on UNESCO actors' mean rating of listed DRM core competencies

Respondents' characteristics	Levels	n	DRM Competency overall	DRM competency: Individual	DRM competency: Practitioner	DRM competency: Relationship
Site type	World Heritage Site	18	4.98	5.05	5.093	4.79
	Biosphere Reserve	62	5.25	5.34	5.40	4.98
	Others	3	4.87	5.07	5.19	4.30
Site location	Africa	15	5.52	5.58	5.53	5.40
	The rest of the world	68	5.10	5.19	5.28	4.80
Job title	UNESCO site staff	19	4.49	4.66	4.68	4.05
	UNESCO site manager	24	5.29	5.34	5.39	5.13
	Others	40	5.43	5.51	5.59	5.19
			**	*	*	**
Age range	25-34 years	11	5.36	5.45	5.45	5.14
	35-44 years	18	4.54	4.67	4.67	4.20
	45-54 years	25	5.29	5.35	5.53	5.01
	55-64 years	19	5.77	5.80	5.80	5.69
	65+ years	4	4.99	5.03	5.36	4.64
			*	*	*	*
Gender	Male	42	5.39	5.45	5.56	5.15
	Female	34	5.03	5.12	5.13	4.78
	Others	1	5.52	5.40	5.86	5.44
Educational level	Non-university graduate	3	5.83	5.98	5.76	5.63
	University-level education	9	5.01	5.03	5.19	4.83
	Postgraduate degree	65	5.23	5.31	5.38	4.98
Length of service	0-5 years	25	5.05	5.09	5.24	4.84

	6-10 years	21	5.21	5.32	5.31	4.95
	11+ years	31	5.39	5.47	5.53	5.14
Sufficiency of collective (family) income	No	12	5.08	5.16	5.25	4.83
	Yes	59	5.31	5.39	5.46	5.07
Housing type	House (free standing)	36	5.48	5.47	5.71	5.31
	Unit/flat (joined to	16	5.17	5.25	5.24	4.97
	another unit/flat)	23	4.92	5.10	4.96	4.56
	Apartment in a multi-level building	2	4.87	4.97	5.29	4.39
	Other (please specify)					
Disaster consequences on site	No consequence	10	4.73	4.7467	5.0143	4.4778
	Gradual (in stages)	33	5.12	5.2343	5.1645	4.9024
	Mild	26	5.08	5.2128	5.2582	4.7308
	Catastrophic/severe	14	5.79	5.7952	6.0306	5.5794
Training attendance	No	16	4.90	5.0875	4.9375	4.5556
	Yes	33	5.38	5.4182	5.5844	5.1650
Damages from past disasters	None	24	4.72	4.83	5.10	4.26
	2	13	5.61	5.62	5.66	5.55
	3	3	4.60	4.53	4.86	4.52
	Moderate	19	5.08	5.25	5.14	4.77
	5	12	5.05	5.21	4.93	4.89
	6	5	5.75	5.73	6.11	5.51
	A lot of damages	7	6.21	6.23	6.24	6.14
			*	*	*	*

* = p <.05; ** = p <.01

II.3.3.3. Dimensions of expressed DRM next-generation core competencies

The PCA results showed four distinct components (Table II.3–3) with eigenvalues above 1, explaining 76.18 % of the total variance in the data set. Four factors ensued with items corresponding to DRM next-generation core competencies relating to (1) individual, practitioner, and relationship components combined; (2) individual and practitioner components combined (3) individual and relationship components combined (4) only the individual component.

In Table 3 items are ordered to show component groupings. The grey shading shows highly positive factor loadings (≥ 0.50). Two components contain ambiguous items with two highly positive loadings. In both cases, items were placed in the component with the higher loading. We subsequently present the deductive interpretations and labels of the four identified components as dimensions of next-generation core competencies for DRM among UNESCO actors. These dimensions illustrate the varying combinations of competencies possessed by UNESCO actors. While some respondents exhibit a holistic competency that encompasses all three components, others demonstrate different combinations of these competencies, as described below.

Table II.3–3: Results of factors (PCs) from the PCA

DRM next-generation core competency items	PC1	PC2	PC3	PC4	DRM core competency type (category)
I use creative and innovative approaches to solving disaster challenges	0.49	0.25	0.41	0.45	Operation within Disaster Risk Management Framework(I)
I consider, utilize, and value the growing body of disaster risk management literature for building disaster-resilient communities	0.64	0.30	0.20	0.51	Operation within Disaster Risk Management Framework(I)
I help others understand the relationship between social factors and disaster risk concentration	0.7	0.28	0.11	0.37	Sociocultural Literacy(P)
I use existing appropriate technologies in disaster risk management practice	0.79	0.06	0.19	0.39	Technological Literacy(P)
I consider ethical, legal, and social implications when determining the appropriateness of a technology application for disaster risk management	0.74	0.21	0.13	0.34	Technological Literacy(P)
I work in partnership with others and utilize a range of resources available within the system to establish an innovative solution to a pressing problem	0.58	0.35	0.50	0.20	Systems Literacy(P)
I clearly communicate and explain hazard risks to a wide range of stakeholders	0.89	0.19	0.12	0.19	Disaster Risk Management(R)
I understand and apply disaster risk management frameworks to identify and manage risks	0.89	0.19	0.08	0.22	Disaster Risk Management(R)
I monitor, evaluate, and review risk management processes and outcomes	0.86	0.11	0.29	0.13	Disaster Risk Management(R)
I involve the stakeholders to focus on the disaster risk exposure	0.82	0.11	0.29	0.35	Community Engagement(R)

I support community networks through the ongoing improvement of collective disaster risk reduction goals and interventions	0.84	0.05	0.18	0.17	Community Engagement(R)
I identify and analyse a hazard risk issue for action	0.83	0.17	0.26	0.07	Governance and Civics(R)
I analyse access to the relational dynamics of, and the ramifications from those in positions of political power, policy, and legal parameters in connection to disaster risk issues	0.84	0.11	0.32	0.19	Governance and Civics(R)
I bring people together across sectors to identify and address disaster risk issues at hand	0.81	0.06	0.34	0.28	Governance and Civics(R)
I inspire a shared vision with community stakeholders and involve them to contribute to its achievement	0.66	0.25	0.60	0.08	Leadership(R)
I empower my staff to successfully pursue our organisation's vision	0.52	0.41	0.48	0.11	Leadership(R)
I resolve conflicts that emerge within or between the organization and the community it serves	0.62	0.26	0.52	0.14	Leadership(R)
I possess critical thinking for problem identification and solutions	0.04	0.78	0.02	-0.01	Critical Thinking(I)
I demonstrate Professional ethics of respect, justice, integrity, and selfless service	0.17	0.88	0.05	0.11	Professional Ethics(I)
I engage in continual learning and knowledge expansion	0.22	0.84	0.17	0.12	Continual Learning(I)
I value a science and knowledge-based approach for continuous improvement	0.18	0.65	0.39	0.34	Operation within Disaster Risk Management Framework(I)
I appreciate scientific processes and how their applications benefit humanity	0.29	0.68	0.42	0.11	Scientific Literacy(P)

The world is made of physical, built, and social systems, which interact in multifaceted ways, producing varying levels of risk and vulnerability	0.19	0.79	0.22	0.26	Geographic Literacy(P)
People and places are connected in a dynamic network of global relationships	-0.05	0.74	0.24	0.19	Geographic Literacy(P)
I create and sustain a team atmosphere to facilitate communication	0.25	0.42	0.62	0.3	Operation within Disaster Risk Management Framework(I)
I facilitate synchronous activities among all relevant stakeholders to achieve a common purpose	0.43	0.34	0.62	0.30	Operation within Disaster Risk Management Framework(I)
I facilitate a community learning process through communication, dialogue, negotiation, and cooperation	0.51	0.25	0.69	0.17	Community Engagement(R)
I consider all hazards, phases, stakeholders, and impacts relevant to disasters	0.30	0.47	-0.03	0.60	Operation within Disaster Risk Management Framework(I)
I expect future disasters and develop disaster-resistant and disaster-resilient communities	0.32	0.25	0.45	0.59	Operation within Disaster Risk Management Framework(I)
I utilize sound risk management principles in assigning priorities and resources	0.37	0.209	0.14	0.67	Operation within Disaster Risk Management Framework(I)
I ensure unity of efforts among all community members to manage disaster risk	0.40	0.09	0.33	0.64	Operation within Disaster Risk Management Framework(I)

Notes:
(I) = DRM competencies that build the individual
(P) = DRM competencies that build the practitioner
(R) = DRM competencies that build the relationships

II.3.3.3.1. Dimension 1: Holistic disaster risk management proficiency

Items with high loadings contained in this dimension encompass the individual, practitioner, and relationship components of the tested DRM next-generation core competencies. More than half of all the tested items and almost two-thirds of the thirteen competency measures were contained in this dimension. While five items are directly related to measures of DRM frameworks at personal and interpersonal levels, the other twelve items are spread among measures of sociocultural literacy, technological literacy, systems literacy, community engagement, governance and civics, and leadership. Thus, the caption holistic DRM proficiency is justified as this dimension incorporates a vast array of DRM next-generation core competencies, and multifaceted literacies linking individual capabilities, DRM innovative practices and interpersonal relationships.

II.3.3.3.2. Dimension 2: Systems thinking and professionalism

The collection of competencies in this dimension reflects a systemic approach to problem-solving and a commitment to professionalism in DRM. The items within this component indicate a mindset geared towards holistic thinking, ethical conduct, continual learning, and a strong appreciation for knowledge-based approaches and scientific processes. An understanding of the interconnectedness of global systems, and the use of scientific processes for continuous improvements warrants the label of systems thinking and professionalism for this dimension.

II.3.3.3.3. Dimension 3: Collaborative coordination and engagement

The third dimension contains competencies that emphasize the facilitation of effective communication, collaboration, and coordination among various stakeholders for DRM. Together, these items covering only two measures (operation within the DRM framework and community engagement) highlight the ability to create and sustain a conducive team environment that fosters open communication, synchronous activities, and collaborative learning. These items are crucial for building relationships, sharing information, and collectively addressing disaster challenges. The choice of the caption collaborative coordination and engagement is due to the cooperation among multiple stakeholders as facilitated by the respondents.

II.3.3.3.4. Dimension 4: Proactive resilience planning

This last dimension from the PCA results focuses on elements of planning and responding to disaster risks for resilience. All items are solely related to the individual DRM competency and cover strategic planning, resource allocation, inclusive and collective actions, and resilience building. The forward-thinking approach warrants the adoption of the term 'proactive' in the label. Moreover, a combination of comprehensive consideration of diverse elements and sound principles within DRM initiatives for resource allocation points to increased effectiveness.

II.3.3.4. DRM next-generation core competencies and site disaster preparedness

The cluster analyses of DRM next-generation core competencies and sites preparedness levels yielded four clusters with a good measure of cohesion and separation of the data (Fig II.3–2). These distinct clusters correspond to very high (cluster 1), very low (cluster 2), high (cluster 3), and moderate (cluster) levels of DRM core competency based on the four-factor PCs. Cluster 1 had the highest membership (n = 31), followed by Cluster 3 (n = 30). The least group membership was recorded in Cluster 2 (n = 5). There is a consistently higher percentage of sites prepared for disasters in all clusters except Cluster 2 (Table II.3–4). Hence, the sites of the majority of those who expressed low DRM next-generation core competencies were also unprepared for disasters.

There was a weak positive but statistically significant relationship of site preparedness with means of the four principal components: PC1 (R = .301**), PC2 (R = .275*), PC3 (R = .292**), and PC4 (R = .272*). Moreover, stepwise regression results (Table 5) show only PC1 mean (i.e., holistic disaster risk management proficiency) as the most relevant predictor of sites' disaster preparedness (R = .301, R2 = .09, p = <.01).

Thus, the cluster analysis identified four distinct clusters representing different levels of DRM core competency: very high, high, moderate, and very low. Additionally, there exists a minor correlation between the possession of DRM competencies and disaster preparedness across UNESCO sites. Similarly, when evaluating predictors of disaster preparedness across all competency dimensions from the PCA, only the holistic DRM competency dimension (i.e., PC 1) emerges, suggesting comprehensive DRM competencies as crucial to disaster preparedness in UNESCO-designated heritage sites.

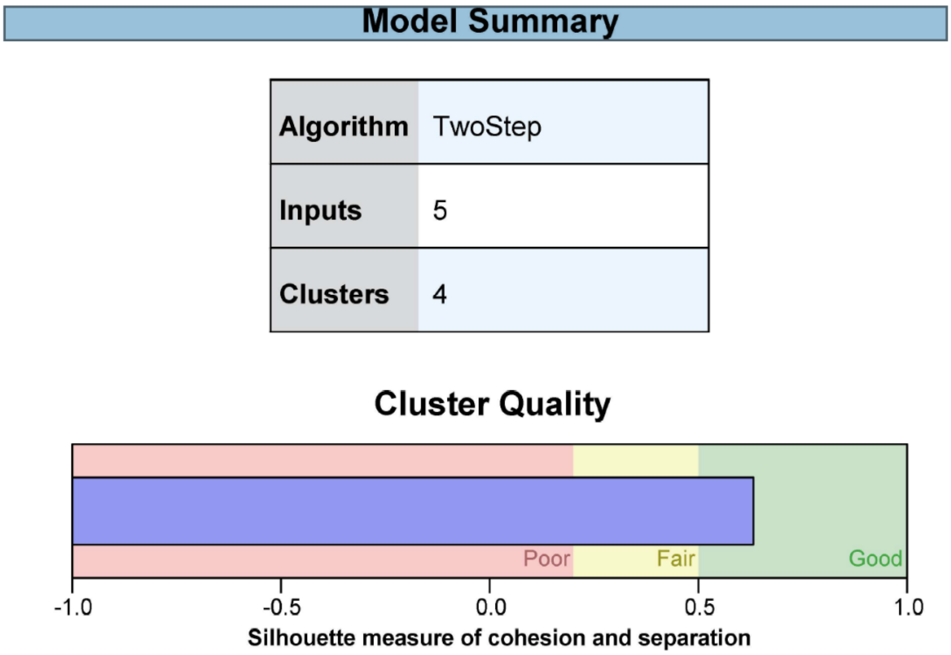

Figure II.3–2: Model summary of cluster analyses

Table II.3–4: Cluster analyses results

Variables (PC mean)	Minimum	Maximum	Mean	Std. Deviation	Cluster 1		Cluster 2		Cluster 3		Cluster 4	
					PC Centroid	% Prep. (Unprep.)	PC Centroid	% Prep. (Unprep.)	PC Centroid	% Prep. (Unprep.)	PC Centroid	% Prep. (Unprep.)
PC1	1.00	7.00	4.92	1.33	6.13		1.84		4.91		3.52	
PC2	1.00	7.00	5.00	1.31	6.20	25.32	1.84	2.53	4.94	26.58	3.73	10.13
PC3	1.00	7.00	4.99	1.31	6.19	(13.92)	1.81	(3.80)	4.97	(11.39)	3.69	(6.33)
PC4	1.00	7.00	5.09	1.26	6.21		1.91		5.06		3.94	

Notes:
PC = Principal Components
Prep. = Prepared
Unprep. Unprepared

Table II.3–5: Stepwise regression of predictors of site disaster preparedness

Model		B	Std. Error	Beta	R^2 adj.	F	t
1	(Constant)	1.972	1.293			7.46**	1.53
	PC1 Mean	0.686	0.251	0.301	0.08		2.73**

n =77

II.3.4. Discussion and implications

The study sought to evaluate the Disaster Risk Management (DRM) core competencies among UNESCO site actors and their connection to disaster preparedness in these sites. Results indicated that most respondents affirmed the listed DRM next-generation core competencies outlined in the study. Factors such as job position, age, and on-site disaster consequences exhibited significant influence on the tested competencies. Moreover, the study identified four principal components delineating the dimensions of competencies held by participating UNESCO actors: holistic disaster risk management proficiency, systems thinking and professionalism, collaborative coordination and engagement, and proactive resilience planning. Notably, respondents with lower DRM next-generation core competencies also demonstrated reduced disaster preparedness, while holistic disaster risk management proficiency emerged as the sole predictor of sites' disaster preparedness.

While UNESCO site actors exhibit a collective strength in possessing robust DRM next-generation core competencies, notable disparities exist across specific competencies, particularly in aspects related to building relationships and demanding attention. Future training initiatives should address this critical skill gap to enhance the competencies among the respondents. According to Feldmann-Jensen et al. (2019), all measures of these competencies play a strategic role in preparing the next generation of the DRM workforce. Furthermore, these competencies are also useful for setting performance standards.

However, there is a scarcity of studies assessing next-generation core competencies in DRM, limiting further discussion and comparison with previous research. Nevertheless, Bhagavathula et al. (2021) utilized similar next-generation core competencies to assess a capacity-building program, highlighting that competencies fostering relationships were the least demonstrated across the three separate training programs they evaluated. Similarly, Durrant et al. (2023) suggest a potential oversight among UNESCO site managers in establishing connections with stakeholders, potentially missing out on meaningful relationships and opportunities to leverage shared resources and knowledge.

The data from this study does not clarify why UNESCO national commissions and focal persons showed significantly higher ratings in DRM competencies compared to others. Such disparities underscore the vital need for knowledge sharing among all stakeholders involved. While Durrant et al. (2023) suggest training as a means for transferring DRM knowledge from experienced WHP professionals to others, Giliberto and Jackson (2022) propose a shift from conventional top-down approaches to more inclusive knowledge exchange solutions across heritage sites and similar settings. The International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) (2023) illustrates such collaborative capacity-building formats, as demonstrated in a recent workshop in Mozambique. During this event, participants collectively developed disaster mitigation, preparedness, and response guidelines through their own field experiences, aiming to integrate these into DRM plans.

In addition, our investigation into DRM next-generation core competencies revealed a trend of higher ratings among older respondents, aligning with existing literature, particularly among emergency nurses. For instance, Yu et al. (2013) identified nurses' age, formal education, and engagement in disaster-related training as influential factors in DRM competency. Similarly, Soltani Goki et al. (2023) noted substantial variations in DRM ratings among nurses based on education level, age, work experience, employment status, and training participation. However, our study did not establish statistical significance in mean DRM competency ratings among respondents based on several factors. Specifically, the site type, site location, disaster consequences on sites, gender, educational level, training participation, length of service, and socioeconomic characteristics like family income sufficiency and housing type are not significant factors of DRM next-generation core competencies among respondents in our study.

Interestingly, our findings show the significance of damages from prior disasters as a substantial factor influencing the DRM core competencies of UNESCO site actors. Experience with disaster repercussions tends to significantly shape the readiness and ability of individuals to manage future similar events. Onuma et al. (2017) opine that persons who have encountered disasters may exhibit an increased risk awareness and better preparedness in comparison to those without such experiences. The relevance of disaster experience as a determinant of disaster preparedness extends the conclusions drawn by Eze and Siegmund (2024b), who identified disaster awareness and the availability of DRM resources as significant factors influencing disaster preparedness in UNESCO-designated heritage sites.

Increased emphasis should be placed on cultivating comprehensive DRM proficiency among UNESCO site actors. All components and measures encompassing DRM next-generation core competencies frameworks like that of Feldmann-Jensen et al. (2019) or more current approaches should serve as a guideline for training initiatives or evaluating same. Nurturing a holistic understanding and application of DRM competencies among UNESCO site actors is critical as it improves the disaster preparedness of the heritage sites they oversee. Thus, the prospects of conserving heritages, fortifying their resilience against disasters, supporting local communities and their economies, and ensuring sustainable socio-environmental futures are thereby improved. UNESCO actors with holistic DRM competencies are better positioned to safeguard our invaluable heritages as irreplaceable assets, serving both current and future generations.

This study marks a significant advancement in assessing DRM core competencies among UNESCO actors, with profound implications for capacity-building efforts, heritage conservation, and the pursuit of sustainable futures. It represents the first comprehensive evaluation of next-generation core competencies for DRM in heritage sites, surpassing mere identification of existing skills by illuminating various competency components through advanced analytical techniques and consideration of diverse factors. Our findings underscore the critical importance of holistic DRM competencies in enhancing disaster preparedness within heritage sites while highlighting the role of experiential learning derived from past disaster experiences in shaping preparedness levels. We provide a blueprint for strengthening disaster resilience strategies in UNESCO sites by deepening the understanding of capacity-building needs. Specifically, we advocate for prioritizing the development of relationship-building skills alongside existing DRM competencies to achieve more comprehensive competency levels among UNESCO actors.

Furthermore, our research suggests the incorporation of simulation-based learning into capacity-building programs. Recent studies, such as that by Tasantab et al. (2023), have demonstrated that integrating simulation-based experiential learning into DRM education enhances learners' ability to apply knowledge and make critical decisions. Experiential learning not only enriches practical experience but also fosters the capacity to engage with diverse perspectives. Therefore, integrating experiential learning into capacity-building programs can effectively simulate disaster experiences for individuals who lack direct exposure to disasters, thereby enhancing disaster preparedness. This approach holds promise for equipping UNESCO actors with the necessary skills and knowledge to navigate complex disaster scenarios and contribute to the resilience of heritage sites.

II.3.5. Conclusion

This study offers a comprehensive analysis of DRM next-generation core competencies held among UNESCO site actors and how these competencies relate to disaster preparedness. Training initiatives that focus on relational competencies to achieve holistic DRM proficiency are required for comprehensive disaster preparedness in UNESCO sites. Moreover, the value of experiential learning is emphasised by this study as past disaster damages tend to shape DRM competencies among responding UNESCO actors. Thus, case studies and real-life experiences should be incorporated into training activities. To address disparities in competency levels due to age and job positions, inclusive knowledge-sharing exchanges among stakeholders and across site contexts are needed.

Our results reveal the need for more studies to develop frameworks aligning with the evolving needs of UNESCO actors for effective DRM in the context of heritage conservation for sustainable futures in the period beyond 2030. Such tailored capacity-building frameworks and subsequent activities become imperative as there are high expectations to witness the accomplishment of major global frameworks such as Agenda 2030 and the Sendai Framework for Disaster Risk Reduction. Further studies, particularly those employing qualitative methods, are imperative to delve deeper into the development process of these competencies. Qualitative approaches can offer rich insights into the different processes of competency development, shedding light on factors influencing variations in competency levels among individuals. Additionally, qualitative research can provide explanations for observed differences in competency levels, offering a more comprehensive understanding of the underlying dynamics at play.

II.3.6. Limitations of the study

Despite the insights gained from the findings of this study, several limitations are acknowledged. Firstly, our utilization of self-reported data in this study introduces potential response bias, where participants might provide socially desirable responses, possibly impacting the accuracy of the measured concepts. Also, responses may not precisely reflect the actual levels of the variables we measured in the study. Furthermore, the study's cross-sectional design limits the incorporation of temporal aspects into variable analyses, lacking a longitudinal perspective. The generalizability of findings may also be restricted as respondents and their sites may only represent a subset, potentially failing to capture variations in DRM next-generation core competencies and disaster preparedness across different regions and types of sites.

To strengthen the reliability and depth of future investigations, it is recommended to complement this research with more comprehensive local or national studies. Additionally, expanding sample sizes in subsequent research can facilitate more rigorous statistical analyses, enhance outcome reliability, improve findings' accuracy, and increase their applicability to diverse contexts. Despite these limitations, this study is pivotal in unveiling the state of the art on the topic of identifying and relating DRM next-generation core competencies of UNESCO site actors to disaster preparedness in UNESCO sites for sustainable futures.

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II.3.7. Appendix

Appendix A:
Emergency preparation items tested in the study with response options Yes/No/Not applicable

1. A well-developed plan and procedures for evacuating people is available
2. General emergency equipment is installed
3. A comprehensive strategy based on the main risks, the location of the property, and available resources and expertise is formulated
4. Alarm systems, special security cordons
5. Coordination between the site staff and security
6. Maps of the property showing specific features such as utility mains, fire exits, fire extinguishers, and others
7. Communication of the emergency plan and procedures to visitors, staff and local residents by easily readable handbooks, manuals, drawings, and signage
8. Organizing awareness-raising activities such as seminars and exhibitions
9. Training and capacity-building on the use of emergency equipment such as fire extinguishers
10. Regular emergency simulation drills in cooperation with external agencies such as fire services
11. Other (please specify)

II.3.7. References

APA. (2016). *Ethical principles of psychologists and code of conduct*. American Psychological Association. Retrieved October 27 from https://www.apa.org/ethics/code/ethics-code-2017.pdf

Ashrafi, B., Kloos, M., & Neugebauer, C. (2021). Heritage Impact Assessment, beyond an Assessment Tool: A comparative analysis of urban development impact on visual integrity in four UNESCO World Heritage Properties. *Journal of Cultural Heritage*, 47, 199-207. https://doi.org/10.1016/j.culher.2020.08.002

Bassily, V., Abufarag, T., & Goubran, S. (2023). Preserving Built Environments for a More Sustainable Future: Built Heritage as a Contributor to the SDGs. In A. Rubbo, J. Du, M. R. Thomsen, & M. Tamke, *Design for Resilient Communities* Cham.

Bhagavathula, S., Brundiers, K., Stauffacher, M., & Kay, B. (2021). Fostering collaboration in city governments' sustainability, emergency management and resilience work through competency-based capacity building. *International Journal of Disaster Risk Reduction*, 63, 102408. https://doi.org/10.1016/j.ijdrr.2021.102408

Botta, M. (2017). The role of heritage in facilitation of sustainable futures: A new approach to heritage as a function of cultural change. Knowledge Futures: *Interdisciplinary Journal of Futures Studies*, 1(1), 115-140. https://research.usc.edu.au/esploro/outputs/journalArticle/The-role-of-heritage-in-facilitation/99451126202621

De Silva, N. (2003). *Preparedness and response for cultural heritage disasters in developing countries*. International symposium proceedings of cultural heritage disaster preparedness and response, Hyderabad, India,

Durrant, L. J., Vadher, A. N., & Teller, J. (2023). Disaster risk management and cultural heritage: The perceptions of European world heritage site managers on disaster risk management. *International Journal of Disaster Risk Reduction*, 89, 103625. https://doi.org/10.1016/j.ijdrr.2023.103625

Elhaik, E. (2022). Principal Component Analyses (PCA)-based findings in population genetic studies are highly biased and must be reevaluated. *Scientific Reports*, 12(1), 14683. https://doi.org/10.1038/s41598-022-14395-4

Eze, E., & Nwagu, E. K. (2021). Dimensions of Teachers' Expressed Capacity Building Needs on Climate Change Education Strategies. *Interdisciplinary Journal of Environmental and Science Education*, 17(4), e2251. https://doi.org/10.21601/ijese/10982

Eze, E., Nwagu, E. K. N., & Onuoha, J. C. (2022). Nigerian teachers' self-reported climate science literacy and expressed training needs on climate change concepts: Prospects of job-embedded situative professional development. *Science Education*, 106(6), 1535-1567. https://doi.org/10.1002/sce.21743

Eze, E., & Siegmund, A. (2024a). Appraising competency gaps among UNESCO-designated heritage site actors in disaster risk reduction innovations. *Progress in disaster science*, 22, 100321. https://doi.org/10.1016/j.pdisas.2024.100321

Eze, E., & Siegmund, A. (2024b). Exploring factors of disaster preparedness in UNESCO-designated heritage sites. *Geography and Sustainability.* https://doi.org/10.1016/j.geosus.2024.04.001

Falk, M., & Hagsten, E. (2023). A management perspective on threats to Cultural World Heritage Sites. *International Journal of Heritage Studies*, 29(3), 167-183. https://doi.org/10.1080/13527258.2023.2176348

Feldmann-Jensen, S., Jensen, S. J., Smith, S. M., & Vigneaux, G. (2019). The next generation core competencies for emergency management. *Journal of Emergency Management*, 17(1), 17-25. https://doi.org/10.5055/jem.2019.0393

Frey, B. S., & Briviba, A. (2020). Revived Originals – A proposal to deal with cultural overtourism. *Tourism Economics*, 27(6), 1221-1236. https://doi.org/10.1177/1354816620945407

Fricker, R. D. (2008). *Sampling methods for web and e-mail surveys*. The SAGE handbook of online research methods. London: SAGE Publications Ltd.

Giliberto, F., & Jackson, R. (2022). *Cultural heritage in the context of disasters and climate change*: Insights from the DCMS-AHRC Cultural Heritage and Climate Change Cohort.

Hoffmann, T. (1999). The meanings of competency. *Journal of European Industrial Training*, 23(6), 275-286. https://doi.org/10.1108/03090599910284650

ICCROM. (2023). *ICCROM facilitates workshop for disaster risk management of Mozambique, World Heritage* sites. International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM). Retrieved November 1 from https://www.iccrom.org/news/iccrom-facilitates-workshop-disaster-risk-management-mozambique-world-heritage-site

Jain, A. K. (2010). Data clustering: 50 years beyond K-means. *Pattern Recognition Letters*, 31(8), 651-666. https://doi.org/10.1016/j.patrec.2009.09.011

Janhonen-Abruquah, H., Topp, J., & Posti-Ahokas, H. (2018). Educating Professionals for Sustainable Futures. *Sustainability*, 10(3), 592. https://doi.org/10.3390/su10030592

Joliffe, I. T. (2002). Princ*ipal Component Analysis for Special Types of Data*. In Principal Component Analysis (pp. 338-372). Springer New York. https://doi.org/10.1007/0-387-22440-8_13

Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika*, 39(1), 31-36. https://doi.org/10.1007/BF02291575

Kaufman, L., & Rousseeuw, P. J. (2009). *Finding groups in data: an introduction to cluster analysis*. John Wiley & Sons.

Kothari, C. R. (2004). *Research methodology: Methods and techniques*. New Age International.

Lehdonvirta, V., Oksanen, A., Räsänen, P., & Blank, G. (2021). Social Media, Web, and Panel Surveys: Using Non-Probability Samples in Social and Policy Research. *Policy & Internet*, 13(1), 134-155. https://doi.org/10.1002/poi3.238

Luo, L., Wang, X., & Guo, H. (2022). Contribution of UNESCO designated sites to the achievement of Sustainable Development Goals. *The Innovation*, 3(3), 100227. https://doi.org/10.1016/j.xinn.2022.100227

Minguez Garcia, B. (2020). Resilient cultural heritage: from global to national levels – the case of Bhutan. *Disaster Prevention and Management: An International Journ*al, 29(1), 36-46. https://doi.org/10.1108/DPM-08-2018-0285

Nikkanen, M., Malinen, S., & Laurikainen, H. (2023). What drives feelings of responsibility for disaster preparedness? A case of power failures in Finland and New Zealand. *Risk, Hazards & Crisis in Public Policy*, 14(3), 188-208. https://doi.org/10.1002/rhc3.12263

Onuma, H., Shin, K. J., & Managi, S. (2017). Household preparedness for natural disasters: Impact of disaster experience and implications for future disaster risks in Japan. *International Journal of Disaster Risk Reduction*, 21, 148-158. https://doi.org/10.1016/j.ijdrr.2016.11.004

Pavlova, I., Fassoulas, C., Watanabe, M., Canet, C., & Cupa, P. (2019). *UNESCO designated sites—natural and cultural heritage sites as platforms for awareness raising*. Contributing paper to GAR.

Pavlova, I., Makarigakis, A., Depret, T., & Jomelli, V. (2017). Global overview of the geological hazard exposure and disaster risk awareness at world heritage sites. *Journal of Cultural Heritage*, 28, 151-157. https://doi.org/10.1016/j.culher.2015.11.001

Pavlova, I., Yasukawa, S., Dousseron, A., & Jomelli, V. (2021). Landslides at UNESCO-designated sites. *Understanding and Reducing Landslide Disaster Risk: Volume 1* Sendai Landslide Partnerships and Kyoto Landslide Commitment 5th, 413-419.

Pedersoli Jr, J. L., Antomarchi, C., & Michalski, S. (2016). *A guide to risk management of cultural heritage.* https://www.iccrom.org/sites/default/files/Guide-to-Risk-Managment_English.pdf

Pharaoh, C. D., & Visser, D. J. (2023). Crisis management competencies: A university stakeholder perspective. *Journal of Contingencies and Crisis Management*,. https://doi.org/10.1111/1468-5973.12508

Reddy, C. K., & Vinzamuri, B. (2018). *A survey of partitional and hierarchical clustering algorithms*. In Data clustering (pp. 87-110). Chapman and Hall/CRC.

Sandford, R. (2019). Thinking with heritage: Past and present in lived futures. *Futures*, 111, 71-80. https://doi.org/10.1016/j.futures.2019.06.004

Soltani Goki, F., Farahmandnia, H., Sabzi, A., Taskiran Eskici, G., & Farokhzadian, J. (2023). Iranian nurses' perceptions of core competencies required for disaster risk management. *BMC Emergency Medicine*, 23(1), 84. https://doi.org/10.1186/s12873-023-00853-3

Spezzano, P. (2021). Mapping the susceptibility of UNESCO World Cultural Heritage sites in Europe to ambient (outdoor) air pollution. *Science of the total environment*, 754, 142345. https://doi.org/10.1016/j.scitotenv.2020.142345

Strebler, M. (1997). Getting the Best Out of Your Competencies. ERIC.

Sutton, J., & Tierney, K. (2006). *Disaster preparedness: Concepts, guidance, and research.* Colorado: University of Colorado, 3(1). https://www.bencana-kesehatan.net/arsip/images/referensi/april/Disaster%20Preparedness%20Concepts_Jurnal.pdf

Tasantab, J. C., Gajendran, T., Owi, T., & Raju, E. (2023). Simulation-based learning in tertiary-level disaster risk management education: a class-room experiment. *International Journal of Disaster Resilience in the Built Environment*, 14(1), 21-39. https://doi.org/10.1108/IJDRBE-04-2021-0045

Trillo, C., Aburamadan, R., Mubaideen, S., Salameen, D., & Makore, B. C. N. (2020). Towards a Systematic Approach to Digital Technologies for Heritage Conservation. Insights from Jordan. *Preservation, Digital Technology & Culture*, 49(4), 121-138. https://doi.org/10.1515/pdtc-2020-0023

UNESCO. (2010). Managing disaster risks for world heritage. UNESCO. Retrieved November 10 from https://whc.unesco.org/document/104522

UNESCO. (2015). *Final Report on the Results of the Second Cycle of the Periodic Reporting Exercise for the Europe Region and Action Plan.* https://whc.unesco.org/document/136521

UNESCO, & ICCROM. (2016). *Endangered heritage: emergency evacuation of heritage collections.* United Nations Educational Scientific and Cultural Organization (UNESCO) & International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM). Retrieved November 1 from https://www.iccrom.org/sites/default/files/2017-12/endangered-heritage_interactive.pdf

UNESCO, ICOMOS, & IUCN. (2010). *Managing disaster risks for world* heritage. https://whc.unesco.org/document/104522

UNGA. (2016). *Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction.* The United Nations. Retrieved October 29, 2023, from https://www.preventionweb.net/files/50683_oiewgreportenglish.pdf

UNISDR. (2009). *Terminology.* United Nations International Strategy for Disaster Reduction (UNISDR). https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction

UNISDR. (2015). *Sendai framework for disaster risk reduction 2015–2030.* United Nations International Strategy for Disaster Reduction Retrieved from https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030/

Wong, S.-C. (2020). Competency definitions, development and assessment: A brief review. *International Journal of Academic Research in Progressive Education and Development*, 9(3), 95-114. http://dx.doi.org/10.6007/IJARPED/v9-i3/8223

Yu, L., Ling, L., Huang, W.-Q., Ya-Na, Y., Jie, D., Chun-Hong, Y., Hui, R., & Xian-Yuan, W. (2013). A disaster response and management competency mapping of community nurses in China. *Iranian journal of public health*, 42(9), 941.

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Name, first name	Eze, Emmanuel	Siegmund, Alexander	
Methodology	✓		
Software			
Validation			
Formal analysis	✓		
Investigation	✓		
Resources	✓	✓	
Data Curation	✓		
Writing-Original Draft	✓		
Writing-Review&Editing	✓	✓	
Visualization	✓		
Supervision		✓	
Project administration	✓	✓	
Funding acquisition	✓		

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Alexander Siegmund		29.07.2024
Name/*Name*	Unterschrift/*Signature*	Datum/*Date*

4

"There is no money going to Sub-Saharan Africa. Full stop. I would like to challenge everybody: Do more." ~ Axel van Trotsenburg

II.4. Appraising competency gaps among UNESCO-designated heritage site actors in disaster risk reduction innovations

Abstract

Communities residing in UNESCO-designated sites, characterised by outstanding universal values, face heightened vulnerability during disasters, necessitating innovative Disaster Risk Reduction (DRR) strategies. The critical role of well-equipped UNESCO site actors in DRR necessary for achieving the goals of broader international frameworks such as Agenda 2030 and the Sendai Framework for Disaster Risk Reduction (SFDRR) warrants this needs assessment study. This study uses a descriptive survey design to assess the competency gaps of UNESCO site actors, including managers and staff, for effective utilisation of DRR innovations (DRRI). Employing the Borich Needs Assessment Model and Ranked Discrepancy Model, an online questionnaire garnered 141 responses from 59 countries. Descriptive statistics, significance tests (at $p < .05$*), correlation tests, Mean Weighted Discrepancy Scores, and Ranked Discrepancy Scores yielded noteworthy findings. Despite recognising the importance of DRRI, respondents demonstrated competence lags, emphasizing the need for tailored training programs. Competency gaps were identified across all 14 listed DRRI, with top priorities including disaster prevention radio, telemetry systems, unmanned aerial vehicles, GIS, remote sensing, resilient materials, and disaster risk insurance. Enhancing competencies in DRRI presents a strategic approach to bolstering disaster preparedness, management, and risk reduction efforts, aligning with global conservation and sustainability goals.*

Keywords: Borich needs assessment model, competency gap assessment, disaster risk reduction (DRR) innovations, heritage conservation, ranked discrepancy model, UNESCO sites

Highlights

- Perceived importance consistently outweighs demonstrated competence in innovative DRR.
- Training needs in DRRI are apparent, irrespective of demographic variations.
- Disaster severity increases the need for competency in innovative DRR.
- Social Networking Services exhibited the highest importance-experience gap from initial results.

II.4.1. Introduction

In recent years, there has been a notable surge in the frequency and severity of disaster events globally. A detailed report by Mizutori and Guha-Sapir (2020) shows that the number of reported disaster events surged by 74.48% from 4,212 events during the 1980–1999 period to 7,348 events between 2000 and 2019. According to the United Nations General Assembly [UNGA] (2016), disasters refer to hazardous events, which lead to losses of any kind and disrupt a community or society's functions by interacting with apparent exposure, vulnerability, and coping capacity.

These events have attendant impacts leading to the loss of human lives, livelihoods, and ecosystems estimated at trillions of dollars. Although globally impactful, previous studies, such as Ferguson (2021); Imperiale and Vanclay (2021); and Machlis et al. (2022) have identified differentials in the distribution of disaster impacts owing to varying degrees of vulnerability and coping capacity. Rahman and Fang (2019) recognize the prospect of geoinformation technologies in explaining different dimensions of multiple hazards.

Communities exposed to hazardous events, especially those with heightened vulnerability due to economic disadvantages or a high concentration of vulnerable groups, often experience more significant losses during disasters. Extensive literature, including findings by Ismail-Zadeh (2022), consistently underscores vulnerability and limited coping capacity as critical factors contributing to the severity of disasters. Additionally, Machlis et al. (2022) predict a rise in recurrent acute disasters—repeated, sequential events significantly affecting specific locations, emphasizing the urgent need for enhanced disaster preparedness and management to bolster community resilience, especially in such specific locations. Moreover, Imperiale and Vanclay (2021) advocate for disaster management strategies grounded in resilience and disaster risk reduction (DRR) paradigms, aligning with global frameworks like the SFDRR 2015–2030 (United Nations International Strategy for Disaster Reduction [UNISDR], 2015). These frameworks aspire to facilitate effective DRR efforts globally, with their principles being disseminated and implemented by individual countries.

The SFDRR is a global policy that seeks a significant reduction in global disaster risks and losses by 2030. It presents four priority areas namely: (1) understanding disaster risk in its multi-dimension; (2) strengthening disaster risk governance at all levels (i.e., national, regional, and global) for disaster risk management (DRM) (3) investing in DRR for resilience (4) enhancing disaster preparedness for effective response and to Build Back Better in recovery, rehabilitation, and reconstruction (UNISDR, 2015). Thus, the SFDRR by UNISDR (2015) underscores the importance of investing in and applying innovation in various ways, such as fostering a multi-level culture of safety and resilience, enhancing measurement tools for robust data collection, analysis, and dissemination, and promoting multi-hazard and solution-driven DRM research.

There is a unanimous consensus among prominent disaster researchers, including Shaw et al. (2016), Adu-Gyamfi et al. (2022), and Aitsi-Selmi et al. (2016), emphasizing the pivotal role of science and technology across all priorities outlined in the SFDRR. However, this study closely aligns with priority '3' of the SFDRR advocating for investments in DRR for resilience. Resilience, defined by UNGA (2016) as the ability to withstand, adapt, and recover from hazards, is reinforced by DRR measures aimed at preventing, reducing, and managing disaster risks. Collectively, DRR and resilience will foster sustainable development. It is unsurprising, therefore, that DRR and resilience are captured in several Sustainable Development Goals (SDGs) especially SDGs 1, 2, 9, 11, and 13 (Imperiale & Vanclay, 2021). Hence, in agreement with Eze and Siegmund (2024), we posit that strengthening DRR and resilience, especially by adoption of innovations, are effective in reducing vulnerability, enhancing coping capacity, and promoting sustainable development.

Innovations play a vital role in mitigating disasters, enhancing coping capacities, and fostering resilience (Hu et al., 2018). According to Kahn (2018), innovation spans three dimensions, being either an outcome, a process, or a mindset. It encompasses sought-after outputs (e.g., products), creative ideas and approaches, and an organizational culture fostering creativity for problem-solving. Hence, innovations extend beyond tangible products and include concepts, approaches, frameworks, and processes (Izumi et al., 2019a). Therefore, harnessing innovative technologies, such as geographic information systems, remote sensing, artificial intelligence (AI), and social media, is essential for effective DRR.

Prior research underscores the significant role of technological innovation in DRR, while calling for increased adoption and utilisation. For example, Manatsa and Sakala (2023) stress the pivotal role of scientific knowledge and evidence-based techniques in managing disaster risks, particularly in Sub-Saharan Africa. They advocate harnessing science and technology innovation, with a specific focus on social media, to substantially reduce losses of lives and property during disasters.

Specifically, Orimoloye et al (2021a) assert that technological innovation has introduced numerous opportunities for enhancing DRR, while stressing the need for increased utilization. Also, Orimoloye et al (2021b) identify five key DRR innovations (DRRI), including geographic information systems, remote sensing, disaster risk insurance, social networking systems, and disaster-resilient materials.

The evolving landscape of science and technology, as described by Shaw (2020), indicates a continuous need for adapting to emerging technologies. Thus, the earlier argument of Rahman and Fang (2019) advocate the infusion of remotely sensed data, real-time digital data, and evidence-based digital cum social data in understanding disaster risks is sustained by subsequent studies. Similarly, Ofli and Imran (2023) highlight the transformative impact of AI on DRR, particularly in mapping, monitoring and communication, affirming the earlier vision of Shaw and Kanbara (2022) that recommends customised technology-supported solutions for at-risk persons and communities.

Moreover, Shaw et al (2016) reinforce the significance of DRRI while providing a set of 15 recommendations for effective adoption and application. This study responds to the emphasis of Shaw, et al (2018) linking successful adoption of science and technology in implementing the SFDRR with the promotion of DRRI through field needs and priorities. As an initial needs assessment, our study appraises the perceived importance, experience, and capacity of UNESCO site actors in important DRRI products (Figure II.4–1). Through this pilot study, we provide foundational insights for immediate capacity building programmes to enhance the skills of respondents for effective DRR, while laying the groundwork for future research. Subsequent sections provide further information on the study's context, approaches, contributions, methods, findings, discussion, and conclusion.

1. GIS and remote sensing	4. Concrete and steel: building material and infrastructure	7. Schools as cyclone shelter	10. Earthquake early warning	13. Rainwater harvesting
2. Unmanned aerial vehicles (drones)	5. Disaster risk insurance of persons and properties	8. Seismic code	11. Doppler radar	14. Electricity resistant survey
3. Social Networking Services (SNS)	6. Disaster prevention radio and telemetry system	9. Seismic micro zonation	12. Disaster resilient material	

Figure II.4–1: List of the 14 DRRI products tested in this study
Source: Izumi et al. (2019a)

II.4.1.1. Context of the study

This study expands on Izumi et al. (2019a) research, which identified 14 effective DRRI through a survey involving academia, NGOs, international organizations, and the private sector. Herein, our focus lies in evaluating the importance, capacity, and existing gaps related to these 14 DRRI products and approaches among actors within the United Nations Educational, Scientific and Cultural Organization (UNESCO) sites. UNESCO actors encompass a varied range of stakeholders engaged in the management, conservation, and promotion of UNESCO-designated sites worldwide. UNESCO categorizes these prominent sites into three main types: Global Geoparks (GGs), Biosphere Reserves (BRs), and World Heritage Properties (WHPs). These sites foster education and research, each renowned for unique geological features, biodiversity conservation landscapes, and outstanding cultural or historical significance with universal values (Pavlova et al., 2019). As of October 2023, there are 195 GGs, 748 BRs, and 1,199 WHPs spread across 48, 168, and 134 countries, respectively.

These UNESCO sites are useful in conserving nature and preserving cultural and historical heritage, thereby fostering a deep connection with history, and promoting sustainable development. Luo et al. (2022) emphasize that UNESCO sites offer opportunities for socioeconomic and environmental advancements at multiple levels, from local communities to global initiatives, thus contributing to the attainment of sustainable development goals (SDGs). Similarly, De Silva (2003), posits that these sites play a significant role in enhancing the quality of life by transmitting the historical significance and the pride of various civilizations. The loss of these natural and cultural treasures would deprive present and future generations of their invaluable benefits.

Regrettably, Pavlova et al., (2017) and (2021) identify over 2,000 UNESCO sites exposed to various natural hazards with over 92% of them vulnerable to at least one natural hazard. Thus, increasing frequency and intensity of hazards, which Sugio (2015) asserts are becoming increasingly challenging to predict would heavily impact the human population, heritage assets and ecosystems of these UNESCO-designated sites. Moreover, Pavlova et al., (2017) caution that, if unchecked, disaster impacts may even lead to the erosion or complete loss of the unique cultural and historical values associated with these sites.

NESCO's World Heritage Capacity-Building Strategy has been pivotal in addressing challenges faced by heritage sites, especially in providing guidelines and tools to establish standards and norms for decision-makers and managers at national and site levels. For example, key document resources such as ‘Managing Natural World Heritage’ and ‘Managing Disaster Risks for World Heritage’ represent important guidelines that could equip UNESCO actors with DRR skills (UNESCO World Heritage Centre, n.d.). However, these documents do not cover DRRI. In contrast, recent tailored trainings in Artificial Intelligence, 3D printing, and AI for flood forecasting demonstrate UNESCO's commitment to integrating technology and innovation into their capacity-building initiatives (UNESCO, 2023). Given the comprehensive nature of the DRRI products determined by Izumi et al. (Fig. II.4–1, 2019a) through a robust interaction with various stakeholders, we consider this list of DRRI worth testing among UNESCO actors. These actors such as sites managers and staff play a crucial role in DRR, and no known study, to date, has assessed their capacity on these DRRI. Hence, this study aims to fill a significant gap in the understanding of UNESCO actors' capacity in DRRI, presenting an opportunity to enhance their effectiveness in DRR efforts through informed training and skill development.

Therefore, in this study we identify the capacity building needs of UNESCO site actors in DRRI (Fig. II.4–1). The overarching question of the study is 'what are the capacity building needs of UNESCO sites actors on DRRI?' Our specific objectives to answer the overarching question will address these research questions:

1. What level of importance do UNESCO site actors attribute to DRRI?
2. What is the current capacity of UNESCO site actors in implementing DRRI?
3. How do demographic factors, disaster exposure, and participation in training programs influence the importance and capacity levels of UNESCO site actors in DRRI?
4. Which DRRI receive the highest demand for capacity development among UNESCO site actors?

II.4.1.2. Methodological approaches of the study

This study employed two methodological approaches to assess training needs: the Borich Needs Assessment Model (BNAM) (Borich, 1980) and the Ranked Discrepancy Model (RDM) (Narine & Harder, 2021). Whereas the BNAM uses the Mean Weighted Discrepancy Score (MWDS), the RDM uses Ranked Discrepancy Scores (RDS). Both models give a quick overview of the capacity of the responding group and show areas of capacity development that should be prioritised. However, the RDM tends to address some shortcomings of the BNAM.

The Borich Needs Assessment Model (BNAM) (Borich, 1980) employs an ordinal scale to discern gaps between respondents' perceived importance of a competency for their job and their actual capacity in that competency. These gaps, also known as discrepancies, signify insufficient ability in vital competencies. Previous research by Witkin and Altschuld (1995) similarly defines 'need' as the disparity between the current state and an ideal situation. After identifying individual discrepancies, the model calculates the overall importance (i.e., sample mean importance) of each competency across the entire sample, a technique acknowledged by Narine and Harder (2021) to minimize individual judgment errors.

In the subsequent stage of the BNAM, each respondent's weighted discrepancy score (WDS) is computed by multiplying their discrepancy score with the sample mean importance assigned to each competency. Subsequently, an average of all WDS values generates the Mean Weighted Discrepancy Score (MWDS), typically falling within the range of -4 to 20 for a 5-point Likert response scale. Negative MWDS scores suggest no necessity for training, indicating a capacity level higher than perceived importance, while positive MWDS scores denote competencies requiring training interventions.

The RDM introduced by Narine and Harder (2021) improves upon the BNAM by eliminating the need for calculating sample mean importance in computing the Weighted Discrepancy Scores (WDS). Instead, it utilizes frequency distribution and rank estimation before assigning relative weights to these ranks. In this model, three types of ranks are derived from each needs assessment dataset– Negative Ranks (NR), Positive Ranks (PR), and Tied Ranks (TR). NR reflects situations where respondents perceive higher importance in a competency than their actual capacity. PR indicates higher capacity compared to perceived importance, while TR signifies an equilibrium between capacity and importance (Narine & Harder, 2021).

This study fulfills the prerequisites outlined by Narine and Harder (2021) for employing both the BNAM and RDM methodologies. Data collection involved a cross-sectional online survey that utilized 5-point Likert scales to assess respondents' perceived importance and competence across the 14 listed DRRI products. The MWDS and RDS provides a comprehensive view of respondents' training needs on DRRI products and approaches within this study. While both methodologies offer insights, the RDS introduces a novel approach to analyze ordinal data, including non-normally distributed responses. Additionally, the RDS scale, ranging from −100 to 100 with an equilibrium at 0, offers an intuitive interpretation of training needs. By integrating both BNAM, an established needs assessment model, and the recently developed RDM, this study ensures a comprehensive approach to obtain optimal results. Table II.4–1 presents a summary of the steps for deriving accurate outputs from both models.

Table II.4–1: Summary of steps for obtaining MWDS and RDS

BNAM		RDM	
i.	List the competencies based on objectives,	i.	List the competencies based on objectives,
ii.	Conduct the survey using a two-part form testing perceived importance and capacity,	ii.	Conduct the survey using a two-part form testing perceived importance and capacity,
iii.	Calculate discrepancy scores (the difference between perceived importance and capacity ratings) for each respondent,	iii.	Calculate ranks (i.e., the number of occurrences when respondents' capacity ratings are less (NR), more (PR) or equal (TR),
iv.	Obtain mean importance score for the entire sample in each listed competency,	iv.	Convert the number of rank (i.e., NR, PR, TR) occurrences into percentages,
v.	Calculate respondent's weighted discrepancy score (WDS),	v.	Obtain the RDS for each listed competency by assigning relative weights to ranks where weighted NR % will be = –1, PR % = 1 and TR % = 0.
vi.	Calculate the mean weighted discrepancy score (MWDS) for each competency.		

II.4.1.3. Contributions of the study

This study plays a pivotal role in advancing DRR initiatives by pinpointing critical competency gaps of UNESCO site actors in the adoption of DRRI. The identified gaps form the basis for a strategic roadmap, guiding targeted training initiatives aimed at fortifying the capabilities of these actors. The rectification of these competency deficiencies is paramount for the improvement of DRR strategies within UNESCO-designated sites. Moreover, this study, by delineating key training needs and priorities, lays the groundwork for comprehensive capacity-building initiatives.

The empowerment of site actors with pertinent skills not only amplifies their effectiveness in the management and response to disasters but also forms the bedrock for sustainable disaster management practices. Well-trained site actors become a cornerstone for safeguarding UNESCO sites, ensuring their continual protection against the adverse impacts of disasters. Importantly, the significance of this study transcends academic exploration. It serves as a catalyst for tangible interventions, policy reforms, and collaborative endeavours. By doing so, the study actively contributes to the overarching resilience and sustainability of UNESCO-designated sites in the face of diverse disasters, preserving these sites for upcoming generations.

II.4.2. Methods

II.4.2.1. Design

This study utilised a descriptive survey research design. According to Kothari (2004), the descriptive survey research design is focused on depicting the status among chosen subjects based on selected variables. Consequently, this design choice was apt for conducting a needs assessment to determine the level of competence and experience of UNESCO actors in using DRRI. Additionally, surveys, as emphasized by Eze et al. (2022), are pivotal in gathering essential information before initiating targeted professional development endeavours.

II.4.2.2. Participants selection and data collection

The study participants are designated as UNESCO actors, denoting individuals from diverse backgrounds and roles, including members of UNESCO National commissions and personnel actively engaged in the management and oversight of UNESCO-designated sites globally. These actors are responsible for site management, conservation, education, policy enactment, community engagement and research and capacity-building initiatives within these locations. We, therefore, recognize the unique insights, extensive experiences, and viewpoints adoption and utilisation of DRRI in performing their duties within these sites, hence the choice of these respondents.

For this research, we adopted a combined sampling approach, utilizing harvested email lists (Fricker, 2008) and river sampling (Lehdonvirta et al., 2021), both falling under the convenience non-probability sampling method. Harvested email lists consist of email addresses gathered from various online platforms, while river sampling involves inviting respondents from a specific population to participate in a survey through links placed on websites or emails. In our study, we collected email addresses of UNESCO actors available online and distributed our survey via email.

However, both sampling methods have limitations, restricting the generalizability of our findings solely to active respondents, and indicating potential coverage bias (Lehdonvirta et al., 2021). This bias arises from differences in internet access, usage patterns, and visit frequencies (Van Dijk, 2005). We disseminated our online survey to 1,009 professional email addresses of UNESCO site actors in two primary phases: from August 2022 to February 2023 and from September to October 2023.

To increase response rates, the survey underwent multiple circulations. Reminders were dispatched in October and November 2022, as well as in February 2023 during the first phase. In the second phase, reminders were sent after the fourth and fifth weeks. Despite these efforts, the response rate stood at 13.98%, yielding

141 received responses. Responding UNESCO actors who participated in our study were associated with a range of designated sites, encompassing World Heritage Sites (n = 27), Biosphere Reserves (n = 101), a single Global Geopark, and a few categorized under 'Others' (n = 7). Respondents classified under the 'Others' category included staff members of UNESCO national commissions, Ramsar sites, national parks, and heritage sites presently under consideration for UNESCO designation.

Hence, participants in our study hail from approximately 59 countries worldwide, offering a diverse perspective across various sites, continents, and contexts (Supplementary material 1 (S1)). In S1, readers can explore an overview of the profiles of participating UNESCO actors in our study, especially details such as the country of the site, length of service/work experience, educational qualifications, gender, and age. While the response rate was moderate, the findings, while not entirely representative and generalisable beyond respondents, offer valuable insights for the preliminary appraisal of competency gaps of UNESCO site actors in the adoption and utilisation of DRRI. Considering the demanding work schedules of respondents, the arguments presented by Pharaoh and Visser (2023) may hold validity. They suggest that an overly surveyed population might experience survey fatigue, leading to reluctance in responding to what they perceive as 'non-essential' surveys (Pharaoh & Visser, 2023).

II.4.2.3. Data collection instrument design and testing

Before initiating this study, no survey specifically assessed the training needs related to the DRRI items identified by Izumi et al. (2019a). Consequently, meticulous steps were taken to ensure the validity and reliability of the data collection instrument used in this research. Firstly, the designed questionnaire underwent face validity assessment by two Professors, postdoctoral researchers, and doctoral students in the Department of Geography at Heidelberg University of Education, Germany. The feedback and suggestions, obtained from one professor and five doctoral students, were carefully considered, and incorporated into the final version of the questionnaire (Supplementary material 2). Modifications related mostly to other variables earlier included and not the list of DRRI.

As suggested during the validation, the survey was translated from English to other UNESCO languages (Arabic, Chinese, French, Portuguese, Russian, and Spanish), then reviewed by native speakers to ensure linguistic accuracy before distribution. Secondly, a pilot study was conducted among respondents in European UNESCO sites, yielding 41 responses. For the pre-test of our questionnaire, we concentrated on European biosphere reserves, aligning with our chosen sampling methods (i.e., harvested email lists and river sampling). This choice was mainly guided by the availability of a thorough and readily accessible list of email addresses of our target respondents online during that period.

An internal consistency test using Cronbach's Alpha was performed, resulting in values of 0.901 and 0.892 for the importance and competency levels of DRRI, respectively, indicating high internal consistency (> 89%) of the questionnaire items. Upon analyzing the entire dataset (n = 141), the reliability results for the importance and competency levels of DRRI were 0.910 and 0.907, respectively, confirming the robustness of the questionnaire items and high level of consistency. Thus, the questionnaire employed in this study is considered both valid and reliable.

II.4.2.4. Data analyses

The collected survey responses underwent analysis using IBM SPSS Statistics (Version 29). Descriptive statistics were applied to characterize respondents and assess their perceived importance and competency levels regarding the listed DRRI. Moreover, to identify differences in competency levels and perceived importance of DRRI, independent t-tests, analysis of variance (ANOVA), and paired t-tests were conducted, while correlation tests were utilized to explore relationships among selected variables. To explain the results of importance and competency levels as indicated by respondents, the following mean ratings scale is applied: not important/no competence or experience = 1.00–1.49; of little importance/little competence or experience = 1.50–2.49; important/average competence or experience = 2.50–3.49; very important/moderately high competence or good experience = 3.50–4.49; and absolutely essential/very high competence or extensive experience = 4.50–5.00.

Calculation of the MWDS was performed using Microsoft Excel 365 using a self-developed template prepared by the lead author. This involved determining the difference between perceived importance and capacity ratings (also known as discrepancy scores or gaps) for each respondent regarding each DRRI. Individual discrepancy scores were multiplied by the mean importance score of the entire sample, resulting in WDS. The MWDS, representing the average of the WDS, denotes the level of gaps or training needs among respondents for each specific DRRI (Table II.4–1). Higher MWDS values indicate greater training needs related to the respective DRRI.

The Nonparametric Wilcoxon rank test was performed using IBM SPSS Statistics (Version 29) to assess paired responses of importance and competency in DRRI. The resulting output provided three ranks: Negative Ranks (NR), Positive Ranks (PR), and Tied Ranks (TR). These ranks were exported from SPSS to Microsoft Excel 365 for further analysis. The occurrence frequencies of the three rank types were converted to percentages and then weighted: Negative Ranks (NR%) were assigned a weight of −1, Positive Ranks (PR%) a weight of 1 and Tied

Ranks (TR%) a weight of 0, thereby producing the Relative Discrepancy Score (RDS) (Table II.4–1). In the case where every individual demonstrates a negative deviation in DRRI competency compared to the perceived importance (i.e., up to 100% Negative Rating), the RDS reaches −100. A negative RDS approaching −100 signifies the degree of negative deviation and the magnitude of training needs expressed by respondents regarding DRRI items.

II.4.2.5. Ethical considerations

The Department of Geography, Heidelberg University of Education, Germany, approved the questionnaire after a self-administered ethical review indicated no potential harm to respondent. This approval satisfied the ethical committee's requirement to proceed without a voting process. The study strictly complied with good scientific practices, such as informed consent, anonymity of responses, data privacy, and the right to withdraw from the study at any time, as enshrined in various ethical codes including the American Psychological Association [APA] (2016). Five persons chose to withdraw from the study.

II.4.3. Results

II.4.3.1. Perceived importance and expressed competence in DRRI

Based on participant ratings, seven items were identified as important, yet participants exhibited minimal or no competence or experience in implementing the listed DRRI (Table II.4–2). Initial findings underscore Social Networking Services (SNS) as the foremost DRRI, depicting the most pronounced gap or training requirement among participants.

Table II.4–2: Importance and competence levels of DRRI approaches and technologies among respondents

Tested DRRI	Importance (I)	Competence/experience (C)	Gap (I–C)	Correlation	Paired sample test (p)
GIS and remote sensing	3.08	1.42	1.66	0.000	.000
Unmanned aerial vehicles (drones)	2.92	1.48	1.44	0.068	.000
Social Networking Services (SNS)	2.83	0.75	2.08	0.188	.000
Concrete and steel: building material and infrastructure	2.82	0.82	2.00	0.313**	.000

Disaster risk insurance of persons and properties	2.64	0.86	1.78	0.236*	.000
Disaster prevention radio and telemetry system	2.60	1.19	1.41	0.132	.000
Schools as cyclone shelter	2.57	0.63	1.94	0.400***	.000
Seismic code	2.18	0.57	1.61	0.306**	.000
Seismic micro zonation	2.13	0.53	1.6	0.249*	.000
Earthquake early warning	2.08	0.33	1.75	0.223*	.000
Doppler radar	2.05	0.54	1.51	0.141	.000
Disaster resilient material	1.81	0.20	1.61	0.232	.000
Rainwater harvesting	1.72	0.31	1.41	0.411***	.000
Electricity resistant survey	1.72	0.27	1.45	0.334***	.000
Cluster mean	**2.36**	**0.70**			

II.4.3.2. Influence of various factors on the DRRI importance and capacity ratings

Testing the mean ratings of the levels of importance and capacity regarding DRRI based on respondent characteristics, including site type, age group, gender, educational level, length of service, accommodation type, site location, and participation in training, did not yield statistically significant differences in UNESCO actors' responses across these groups (Table II.4–3). Therefore, irrespective of the various individual characteristics tested in the study, the perceived importance and competency of respondents in the listed DRRI consistently surpassed the demonstrated competence or experience in the same.

Table II.4–3: Mean and standard deviation of DRRI item responses based on respondents' characteristics

Respondents' characteristics	Level	DRRI Importance Mean (SD)	DRRI Competence Mean (SD)
Site type	World Heritage Site	2.1(1.04)	0.72(0.54)
	Biosphere Reserve	2.42(0.87)	0.69(0.74)
	Others	1.46(1.33)	0.38(0.39)
	Total	2.31(0.94)	0.68(0.69)
Age group	18-24 years	2.92	1.50
	25-34 years	2.98(0.82)	0.94(1.13)
	35-44 years	2.16(1.11)	0.59(0.68)
	45-54 years	2.22(0.73)	0.61(0.42)
	55-64 years	2.48(0.76)	0.67(0.68)
	65+ years	1.92(1.32)	1.21(0.89)

	Total	2.36(0.9)	0.7(0.7)
Gender	Male	2.24(0.71)	0.66(0.62)
	Female	2.53(1.09)	0.78(0.79)
	Others	2.0	0.29
	Total	2.36(0.9)	0.7(0.7)
Educational level	Non-university graduate	2.72(0.65)	0.98(1.33)
	University-level education	2.61(0.68)	0.75(0.74)
	Postgraduate degree	2.31(0.94)	0.69(0.67)
	Total	2.36(0.9)	0.7(0.7)
Length of service	0-5 years	2.19(1.01)	0.5(0.43)
	6-10 years	2.63(0.83)	0.84(0.89)
	11+ years	2.32(0.83)	0.78(0.7)
	Total	2.36(0.9)	0.7(0.7)
Accommodation type	Other (please specify)	2.19(0.38)	0.29(0.4)
	House (free standing)	2.38(0.89)	0.74(0.68)
	Unit/flat (joined to another unit/flat)	2.26(1.3)	0.7(0.99)
	Apartment in multi-level building	2.42(0.6)	0.69(0.5)
	Total	2.36(0.9)	0.7(0.7)
Site location	Africa	0.77(0.53)	2.41(0.96)
	The rest of the world	0.66(0.72)	2.29(0.94)
Training attendance	No	0.77(0.76)	2.32(0.91)
	Yes	0.67(0.67)	2.1(0.94)

Upon a deeper exploration of the relationship between general disaster consequences (ranging from no consequence [0] to catastrophic/severe [3]) and perceived importance as well as capacity levels of DRRI, a low yet significant positive correlation was observed between disaster consequences and DRRI competency. Furthermore, Table II.4–4 illustrates a weak but positive and significant correlation between the perceived importance of DRRI and the demonstrated DRRI competency.

Table II.4–4: Pearson correlation results

Variables		Disaster consequences	DRRI competency	DRRI importance
Disaster consequences	Pearson Correlation	--		
	Sig. (2-tailed)			
	N	95		
DRRI competency	Pearson Correlation	.229*	--	
	Sig. (2-tailed)	.038		
	N	83	86	
DRRI importance	Pearson Correlation	.120	.287**	--
	Sig. (2-tailed)	.280	.009	
	N	83	83	83

II.4.3.3. Top ranking DRRI with the highest demand for capacity development

Table II.4–5 presents a comparative analysis of the results obtained from the Borich and Ranked Discrepancy Models (BMAN and RDM, respectively). Both models indicate a noticeable disparity in experience or competence levels related to the implementation of DRRI among participating UNESCO actors. Intriguingly, the top five priority DRRI were nearly identical in both models, except for 'disaster resilient material,' which ranked 4th in the Borich model but was positioned at 14th in the RDM.

Table II.4–5: Top-ranked DRRI requiring for capacity development among UNESCO sites actors

DRR Items	Scores		Rank by model	
	MWDS	RDS	Borich	RDM
Disaster prevention radio and telemetry system	5.90	-78.31	1	2
Unmanned aerial vehicles (drones)	5.64	-75.90	2	3
GIS and remote sensing	5.13	-71.08	3	4
Disaster resilient material	4.98	-16.87	4	14
Disaster risk insurance of persons and properties	4.70	-78.31	5	1
Social Networking Services (SNS)	4.18	-62.65	6	8
Rainwater harvesting	3.67	-59.04	7	11
Earthquake early warning	3.67	-60.24	8	10

Concrete and steel: building material and infrastructure	3.52	-69.88	9	5
Electricity resistant survey	3.42	-63.86	10	7
Schools as cyclone shelter	3.08	-63.86	11	6
Doppler radar	2.90	-61.45	12	9
Seismic micro zonation	2.51	-54.22	13	13
Seismic code	2.43	-54.22	14	12

We conducted a separate analysis using data solely from African UNESCO site actors, the results are presented in Table II.4–6. Interestingly, the top eight DRRI displayed consistent rankings between both the Borich model and RDM, demonstrating minimal differences of no more than one place. Additionally, we observe that the rankings of the first six DRRI in Table II.4–6 closely mirror the outcomes obtained from the global respondent dataset in Table II.4–5, albeit with slightly different positions.

Table II.4–6: Top-ranked DRRI requiring for capacity development among African UNESCO site actors

DRR Items	Scores		Rank by model	
	MWDS	RDS	Borich	RDM
Unmanned aerial vehicles (drones)	8.05	-93.33	1	1
GIS and remote sensing	6.74	-86.67	2	2
Disaster prevention radio and telemetry system	5.81	-80.00	3	4
Disaster risk insurance of persons and properties	5.43	-86.67	4	3
Social Networking Services (SNS)	4.22	-66.67	5	6
Disaster resilient material	4.12	-73.33	6	5
Doppler radar	4.00	-66.67	7	8
Schools as cyclone shelter	3.12	-66.67	8	7
Earthquake early warning	3.02	-60.00	9	10
Concrete and steel: building material and infrastructure	3.00	-53.33	10	11
Rainwater harvesting	2.56	-53.33	11	13
Seismic micro zonation	2.49	-60.00	12	9
Seismic code	2.19	-53.33	13	12
Electricity resistant survey	1.81	-53.33	14	14

II.4.4. Discussion

This initial gap assessment of DRRI competence among UNESCO-designated site actors reveals valuable insights into the perceived importance and demonstrated competency levels associated with identified DRRI. The notable gap in competency/experience despite the identification of DRRI as important underscores a critical need for tailored training programs to bridge this divide. Moreover, the consistent pattern of perceived importance surpassing demonstrated competence across various demographic factors underscores the universal need for enhanced training initiatives. This finding has broad implications for disaster preparedness efforts, providing guidance to align training programs with identified gaps.

Addressing these competency gaps holds paramount importance in enhancing the effectiveness of DRR initiatives, as a well-trained workforce is indispensable for ensuring efficient DRR. Sutton and Tierney (2006) emphasize the pivotal role of resources, particularly human resources, in the effectiveness of DRR activities and preparedness. Their viewpoint underscores that the efficacy of DRR efforts heavily relies on available resources, with a key focus on human resources. They assert that skilled and adequately trained personnel are crucial assets within the realm of DRR. This perspective emphasizes the critical necessity of a competent and well-prepared workforce as a fundamental element contributing to the success of DRR initiatives, especially in developing customised technology-supported solutions as recommended by Shaw and Kanbara (2022).

Enhancing competencies in DRRI, particularly addressing the identified top-ranking gaps in this study, has the potential to significantly strengthen disaster preparedness, management, and risk reduction efforts. For instance, leveraging geospatial technologies such as unmanned aerial vehicles (drones), Geographic Information Systems (GIS), and remote sensing tools can collectively contribute to hazard mapping. Fontes de Meira and Bello (2020) highlight the utility of these technologies in risk assessments, preparedness, and evacuation, underscoring their pivotal role in advancing DRR.

Furthermore, as highlighted by Orimoloye et al (2021a) and recommended by Orimoloye et al (2021b), these geospatial technologies have not only improved the orientation of hazard mappings but have also contributed to the overall advancement of DRR. Moreover, given contemporary and transformative trends in the use of AI for DRR as indicated by Ofli and Imran (2023), the potential of mapping, monitoring and communication during hazards could be further enhanced by developing skills in the use of these geoinformation tools.

In a similar vein, the Japanese Bosai musen disaster prevention radio systems play a pivotal role in disseminating crucial disaster information to residents, thereby significantly enhancing community preparedness and response efforts (Izumi, 2019b). Simultaneously, a telemetry system, as outlined by Izumi (2019b), provides a platform for real-time monitoring of environmental conditions and various disaster situations, including earthquakes, volcanoes, and floods. The synergy between these systems fulfills the operational requirements of DRR, demonstrating their multifaceted utility in augmenting overall disaster management capabilities. Moreover, Rahman and Fang (2019) find the integration of various data sources as essential in understanding disaster risks.

Disaster risk insurance for individuals and properties doesn't inherently prevent or mitigate the risk of damage or loss. However, the financial liquidity it provides post-disaster plays a vital role in alleviating indirect consequences such as reducing human suffering, compensating for the loss of livelihoods and assets, and minimizing setbacks to overall development (Warner et al., 2009). Described by Sheehan et al. (2023) as a risk pooling mechanism for modern society and commerce, insurance effectively reduces the economic impact of disasters. In these ways, insurance acts as a crucial financial tool to enhance resilience and facilitate recovery in the face of unforeseen challenges. Moreover, according to Izumi (2019b), the innovation in insurance extends to emerging applications like Catastrophic Bonds, Resilience Bonds, and InsuResilience. These innovative approaches demonstrate the evolving role of insurance as a crucial financial tool, enhancing resilience and facilitating recovery in the face of unforeseen challenges, thereby contributing to a more adaptive and responsive DRM landscape.

The widespread adoption of computers and smartphones has facilitated the extensive use of Social Networking Sites (SNS), emerging as crucial tools for Disaster Risk Reduction (DRR) and community resilience, as emphasized by Izumi (2019b). SNS fulfill various roles in the realm of DRR, functioning as platforms for hazard education, disaster impact data collection, and information dissemination during crises. Specifically, Manatsa and Sakala (2023) advocate for the utilization of social media to substantially reduce losses of lives and property during disasters. While acknowledging the potential for rumors and false alarms to spread rapidly through SNS, their utilization remains pivotal for DRR efforts. Despite the challenges posed by misinformation, SNS significantly contribute to DRR. These platforms play a vital role in monitoring situations, extending emergency response and management efforts, fostering crowd-sourcing and collaborative development, creating social cohesion, supporting charitable causes through donations, and enhancing research, as highlighted by Alexander (2014). The multifaceted contributions of SNS underscore their positive impact on overall disaster resilience and response, despite the occasional drawbacks.

The identified competency gaps in DRRI items underscore the critical need to invest in training programs aimed at strengthening the capabilities of UNESCO site actors in addressing the escalating frequency of disasters. Enhanced competence in DRRI among site actors directly contributes to safeguarding and preserving UNESCO sites. These innovations play a pivotal role in mitigating environmental impacts and maintaining the delicate balance of these universally unique ecosystems and cultural assets. Moreover, the DRRI tested in this study are only one facet within a broader skill set indispensable for effective DRR in UNESCO sites.

To illustrate, Feldmann-Jensen et al. (2019) earlier introduced an encompassing framework comprising 13 core competencies, known as the Next Generation Core Competencies. Designed to address the challenges of the evolving environmental landscape beyond 2030, these competencies encompass scientific, geographic, sociocultural, technological, and system literacy, as well as DRM, community engagement, governance, professionalism, and related aspects. These competencies could also enable the utilisation of the DRRI tested in this study. Despite the significance of this framework, studies scrutinizing its applicability are limited, demanding further attention in the existing literature.

Furthermore, regardless of the valuable insights provided by this study, it is not without limitations. This study presents a somewhat technocentric perspective in assessing DRRI and fails to adequately encompass broader capacities in soft skills required for DRR as with Feldmann-Jensen at al. (2019). In recognition of the need for a more robust discussion on capacities of UNESCO actors for DRR, the authors are conducting a separate study exploring the next-generation core competencies essential for DRM. Potential biases or constraints in data collection is acknowledged. Also, the use of self-reported measures may not accurately reflect the actual levels of capacity in DRRI.

Future research should include more in-depth investigations into contextual factors influencing competency, longitudinal studies assessing training effectiveness and tracking post-training changes are required. In addition, both the MWDS and RDS do not suggest that every respondent has (in)sufficient competency. These scores only give an overview of the entire sampled group. The reliability and depth of this study's findings could be enhanced using more comprehensive local/national studies. Also, expanding the sample sizes in future research facilitates more rigorous and robust statistical analyses, increased reliability of outcomes, higher accuracy in findings and generalisability. Despite these limitations, this needs assessment research advances the understanding of capacity gaps in the understanding of DRRI competence among UNESCO site actors, offering valuable insights for future research, training initiatives, and disaster preparedness strategies.

II.4.5. Conclusion

This study has uncovered significant training needs in DRRI among responding UNESCO site actors in 59 countries, emphasizing the importance of tailored training programs. While global consistencies in these needs are apparent, the study underscores the urgency of adapting training initiatives to regional contexts, acknowledging the unique vulnerabilities and specific requirements of diverse areas. Moving forward, it is imperative to develop adaptable programs that accommodate the varied backgrounds of UNESCO site actors, fostering resilient conservation efforts across globally designated sites. The positive correlation observed between general disaster consequences and DRRI competency, indicating enhanced responses with escalating disaster severity, reinforces the urgent need for competence in DRRI. This finding serves as a compelling call to action, emphasizing the critical role of enhanced competency in effectively managing intensifying disasters.

Furthermore, the identification of top priorities among UNESCO site actors, including disaster prevention radio, telemetry systems, unmanned aerial vehicles, geographic information systems (GIS), remote sensing, disaster-resilient materials, and disaster risk insurance, offer essential insights for shaping future capacity-building programs. These priorities serve as a valuable roadmap for targeted interventions, highlighting the necessity of equipping UNESCO site actors with technological knowledge and skills to address contemporary challenges effectively. In planning future training initiatives, it is crucial to acknowledge identified gaps and prioritize regions susceptible to severe disasters. Since the preservation of natural and cultural assets within UNESCO sites ultimately relies on the competence of UNESCO site actors, investing in their training translates to better-equipped personnel capable of advancing DRR, aligning with broader conservation and sustainability goals, as well as global frameworks such as Agenda 2030 and the SFDRR. Hence, the connections between adoption of DRRI and implementations of the SFDRR as given by Shaw et al (2018) is reinforced by our findings.

In conclusion, we recognize that DRRI represent just one component of the broader DRM competencies, as highlighted by Feldmann-Jensen et al. (2019). In line with this understanding, we are presently engaged in assessing the possession of a more comprehensive set of next-generation DRM competencies among UNESCO site actors. This ongoing investigation aims to contribute to a more robust discussion on the competency gaps observed among UNESCO site actors. Future studies delving into more in-depth analyses of the effectiveness of capacity-building initiatives will further enhance our nuanced understanding of the evolving research theme of DRR in UNESCO sites. Moreover, the future incorporation of established theoretical frameworks, such as technology acceptance models or the diffusion of innovation theory, could significantly enhance the depth and theoretical underpinnings of this pilot study, yielding results on factors influencing the adoption, implementation, and impact of DRRI. Hopefully, these endeavours will collectively contribute to advancing knowledge, refining strategies, and fostering resilient conservation efforts within these dynamic global landscapes for their sustainability.

CRediT authorship contribution statement

Emmanuel Eze: Writing–review & editing, Writing–original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Alexander Siegmund:** Writing–review & editing, Supervision, Resources.

Declaration of competing interest

The authors declare that there are no known competing financial interests or personal relationships that influenced the work reported in this paper.

Data availability

The authors do not have permission to share data.

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II.4.6. References

Adu-Gyamfi, B., Zuquan, H., Yamazawa, N., Kato, A., & Shaw, R. (2022). Reflections on science, technology and innovation on the aspirations of the Sendai framework for disaster risk reduction. *International Journal of Disaster Resilience in the Built Environment.* https://doi.org/10.1108/IJDRBE-06-2022-0062

Aitsi-Selmi, A., Murray, V., Wannous, C., Dickinson, C., Johnston, D., Kawasaki, A., Stevance, A. & Yeung, T. (2016). Reflections on a science and technology agenda for 21st century disaster risk reduction: Based on the scientific content of the 2016 UNISDR science and technology conference on the implementation of the Sendai framework for disaster risk reduction 2015–2030. *International*

Journal of Disaster Risk Science, 7, 1-29. https://doi.org/10.1007/s13753-016-0081-x

Alexander, D. E. (2014). Social media in disaster risk reduction and crisis management. *Science and engineering ethics*, *20*, 717-733. https://doi.org/10.1007/s11948-013-9502-z

American Psychological Association (2016). *Ethical principles of psychologists and code of conduct.* https://www.apa.org/ethics/code/ethics-code-2017.pdf

Borich, G. D. (1980). A needs assessment model for conducting follow-up studies. *Journal of Teacher Education*, 31(3), 39-42. https://doi.org/10.1177/002248718003100310

De Silva, N. (2003, November). Preparedness and response for cultural heritage disasters in developing countries. *International symposium proceedings of cultural heritage disaster preparedness and response*, Hyderabad, India (pp. 23-27). https://static1.squarespace.com/static/59714798893fc00b04ac9a36/t/598d32cae3df2828b07f29c7/1502425802975/de_silva_Disaster+Preparedness.pdf

Eze, E., Nwagu, E. K., & Onuoha, J. C. (2022). Nigerian teachers' self-reported climate science literacy and expressed training needs on climate change concepts: Prospects of job-embedded situative professional development. *Science Education*, 106(6), 1535-1567. https://doi.org/10.1002/sce.21743

Eze, E., & Siegmund, A. (2024). Identifying disaster risk factors and hotspots in Africa from spatiotemporal decadal analyses using INFORM data for risk reduction and sustainable development. *Sustainable Development*, 1–22. https://doi.org/10.1002/sd.2886

Feldmann-Jensen, S.; Jensen, S.J.; Smith, S.M.; Vigneaux, G. (2019). The next generation core competencies for emergency management. *Journal of Emergency Management*, 17, 17-25, https://doi.org/10.5055/jem.2019.0393.

Ferguson, N. (2021). *Doom: The politics of catastrophe*. Penguin UK.

Fontes de Meira, L., & Bello, O. (2020). *The use of technology and innovative approaches in disaster and risk management: a characterization of Caribbean countries' experiences.* Studies and Perspectives series-ECLAC Subregional Headquarters for the Caribbean, No. 93 (LC/TS.2020/106-LC/CAR/TS.2020/3), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC). https://repositorio.cepal.org/server/api/core/bitstreams/d1f94a03-ab00-4b25-9b3d-98239b5327c1/content

Fricker, R.D. (2008). *Sampling methods for web and e-mail surveys*. The SAGE handbook of online research methods. London: SAGE Publications Ltd.

Hu H, Lei T, Hu J, Zhang S, Kavan P. (2018). Disaster-mitigating and general innovative responses to climate disasters: Evidence from modern and historical

China. *International Journal of Disaster Risk Reduction* (28), 664–73. https://doi.org/10.1016/j.ijdrr.2018.01.022.

Imperiale, A. J., & Vanclay, F. (2021). Conceptualizing community resilience and the social dimensions of risk to overcome barriers to disaster risk reduction and sustainable development. *Sustainable Development*, 29(5), 891-905.

Ismail-Zadeh, A. (2022). Natural hazards and climate change are not drivers of disasters. *Natural Hazards* 111, 2147–2154. https://doi.org/10.1007/s11069-021-05100-1

Izumi, T., Shaw, R., Djalante, R., Ishiwatari, M., & Komino, T. (2019a). Disaster risk reduction and innovations. *Progress in Disaster Science*, 2, 100033. https://doi.org/10.1016/j.pdisas.2019.100033

Izumi, T., Shaw, R., Ishiwatari, M., Djalante, R., & Komino, T. (2019b). *Thirty innovations for disaster risk reduction.* International Institute of Disaster Science (IRIDeS) at Tohoku University, Keio University, the University of Tokyo, the United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS), and Church World Service (CWS) Japan. https://collections.unu.edu/eserv/UNU:7274/n30_Innovations_for_Disaster_Risk_Reduction_final.pdf

Kahn, K.B. (2018). Understanding innovation. *Business Horizons,* 61(3), 453–60. https://doi.org/10.1016/j.bushor.2018.01.011

Kothari, C.R. (2004). *Research methodology: Methods and techniques.* New Age International.

Lehdonvirta, V., Oksanen, A., Räsänen, P. & Blank, G., 2021. Social media, web, and panel surveys: Using non-probability samples in social and policy research. *Policy & internet*, 13(1), 134-155. https://doi.org/10.1002/poi3.238

Luo L., Wang X., and Guo H. (2022). Contribution of UNESCO designated sites to the achievement of Sustainable Development Goals. *The Innovation* 3(3), 100227. https://doi.org/10.1016/j.xinn.2022.100227

Machlis, G. E., Román, M. O., & Pickett, S. T. (2022). A framework for research on recurrent acute disasters. *Science Advances*, 8(10), eabk2458. https://doi.org/10.1126/sciadv.abk2458

Manatsa, D., & Sakala, L. (2023). Harnessing Scientific Knowledge and Technological Innovation for Disaster Risk Reduction (DRR) in Sub-Saharan Africa-Case of Social Media. In: Tatano, H., Collins, A. (eds) *Proceedings of the 4th Global Summit of Research Institutes for Disaster Risk Reduction.* GSRIDRR 2019. Disaster and Risk Research: GADRI Book Series. Springer, Singapore. https://doi.org/10.1007/978-981-19-5566-2_7

Mizutori, M., & Guha-Sapir, D. (2020). *Human cost of disasters: An overview of the last 20 years (2000-2019).* Centre for Research on the Epidemiology of Disasters (CRED) and United Nations Office for Disaster Risk Reduction (UNDRR), Belgium and Switzerland.

https://www.undrr.org/sites/default/files/inline-files/Human%20Cost%20of%20Disasters%202000-2019%20FINAL.pdf. Retrieved on October 29, 2023

Narine, L., & Harder, A. (2021). Comparing the Borich model with the Ranked Discrepancy Model for competency assessment: A novel approach. *Advancements in Agricultural Development*, 2(3), 96-111. https://doi.org/10.37433/aad.v2i3.169

Ofli, F., & Imran, M. (2023). *Introduction: Emerging Technologies and Innovative Applications of AI in DRR*. In: Singh, A. (eds) *International Handbook of Disaster Research*. Springer, Singapore. https://doi.org/10.1007/978-981-16-8800-3_210-1

Orimoloye, I. R., Belle, J. A., & Ololade, O. O. (2021a). Exploring the emerging evolution trends of disaster risk reduction research: a global scenario. *International Journal of Environmental Science and Technology*, 18, 673-690. https://doi.org/10.1007/s13762-020-02847-1

Orimoloye, I. R., Ekundayo, T. C., Ololade, O. O., & Belle, J. A. (2021b). Systematic mapping of disaster risk management research and the role of innovative technology. *Environmental Science and Pollution Research*, 28, 4289-4306. https://doi.org/10.1007/s11356-020-10791-3

Pavlova, I., Fassoulas, C., Watanabe, M., Canet, C., & Cupa, P. (2019). *UNESCO designated sites—natural and cultural heritage sites as platforms for awareness raising*. Contributing paper to GAR.

Pavlova, I., Makarigakis, A., Depret, T., & Jomelli, V. (2017). Global overview of the geological hazard exposure and disaster risk awareness at world heritage sites. *Journal of Cultural Heritage*, 28, 151-157. https://doi.org/10.1016/j.culher.2015.11.001

Pavlova, I., Yasukawa, S., Dousseron, A., Jomelli, V. (2021). Landslides at UNESCO-Designated Sites. In: Sassa, K., Mikoš, M., Sassa, S., Bobrowsky, P.T., Takara, K., Dang, K. (eds) *Understanding and Reducing Landslide Disaster Risk*. WLF 2020. ICL Contribution to Landslide Disaster Risk Reduction. Springer, Cham. https://doi.org/10.1007/978-3-030-60196-6_33

Pharaoh, C. D., & Visser, D. J. (2023). Crisis management competencies: A university stakeholder perspective. *Journal of Contingencies and Crisis Management,* 1-8, DOI: 10.1111/1468-5973.12508

Rahman, A. U., & Fang, C. (2019). Appraisal of gaps and challenges in Sendai framework for disaster risk reduction priority 1 through the lens of science, technology and innovation. *Progress in disaster science*, 1, 100006. https://doi.org/10.1016/j.pdisas.2019.100006

Sheehan, B., Mullins, M., Shannon, D., & McCullagh, O. (2023). On the benefits of insurance and disaster risk management integration for improved climate-related natural catastrophe resilience. *Environment Systems and Decisions*, 1-10. https://doi.org/10.1007/s10669-023-09929-8

Shaw, R. (2020). Thirty Years of Science, Technology, and Academia in Disaster Risk Reduction and Emerging Responsibilities. *International Journal of Disaster Risk Science*, 11, 414–425. https://doi.org/10.1007/s13753-020-00264-z

Shaw, R., & Kanbara, S. (2022). Science, Technology, Innovation and Sendai Framework for Disaster Risk Reduction. In: Kanbara, S., Shaw, R., Kato, N., Miyazaki, H., Morita, A. (eds) *Society 5.0, Digital Transformation and Disasters. Disaster Risk Reduction*. Springer, Singapore. https://doi.org/10.1007/978-981-19-5646-1_2

Shaw, R., Izumi, T. & Shi, P. (2016). Perspectives of Science and Technology in Disaster Risk Reduction of Asia. *International Journal of Disaster Risk Science*, 7, 329–342. https://doi.org/10.1007/s13753-016-0104-7

Shaw, R., Izumi, T., & Shiwaku, K. (2018). Science and technology in disaster risk reduction in Asia: Post-Sendai developments. In *Science and technology in disaster risk reduction in Asia* (pp. 3-16). Academic Press. https://doi.org/10.1016/B978-0-12-812711-7.00001-8

Sugio, K. (2015) Large-scale Disasters on World Heritage and Cultural Heritage in Japan: Significant Impacts and Sustainable Management Cases, *Landscape Research*, 40 (6), 748-758, DOI: 10.1080/01426397.2015.1057806

Sutton, J., & Tierney, K. (2006). *Disaster preparedness: Concepts, guidance, and research.* Report prepared for the Fritz Institute Assessing Disaster Preparedness Conference Sebastopol, California, November 3 and 4, 2006. https://doi.org/10.1007/s13762-020-02847-1

United Nations Educational Scientific and Cultural Organization (UNESCO) (2023, May 11). *Knowledge, science, Technology and Innovation for Resilience.* UNESCO.org. https://www.unesco.org/en/disaster-risk-reduction/sti

UNESCO World Heritage Centre. (n.d.). *Managing disaster risks for world heritage.* https://whc.unesco.org/en/managing-disaster-risks/

United Nations General Assembly [UNGA] (2016). *Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction.* https://www.preventionweb.net/files/50683_oiewgreportenglish.pdf. Retrieved on October 29, 2023

United Nations International Strategy for Disaster Reduction [UNISDR], (2015). *Sendai framework for disaster risk reduction 2015–2030. Paris: United Nations Office for Disaster Risk Reduction.* https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf. Retrieved on October 29, 2023

Van Dijk, J. 2005. *The Deepening Divide: Inequality in the Information Society.* London: Sage.

Warner, K., Ranger, N., Surminski, S., Arnold, M., Linnerooth-Bayer, J., Michel-Kerjan, E., ... & Herweijer, C. (2009). *Adaptation to Climate Change: Linking Disaster Risk Reduction and Insurance.* A paper prepared for the United Nations International Strategy on Disaster Reduction (UNISDR). https://www.unisdr.org/files/9654_linkingdrrinsurance.pdf

Witkin, B. R., & Altschuld, J. W. (1995). *Planning and conducting needs assessments: A practical guide.* Sage.

Supplementary material

Supplementary 1: Profile of responding UNESCO actors in the study. *See Appendix 3 for this information.*

Supplementary 2: Instrument of data collection (i.e., the questionnaire). *See Appendix 2 for this information.*

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Name, first name	Eze, Emmanuel	Siegmund, Alexander	
Methodology	✓		
Software			
Validation			
Formal analysis	✓		
Investigation	✓		
Resources	✓	✓	
Data Curation	✓		
Writing-Original Draft	✓		
Writing-Review&Editing	✓	✓	
Visualization	✓		
Supervision		✓	
Project administration	✓	✓	
Funding acquisition	✓		

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5

"Remember: when disaster strikes, the time to prepare has passed." ~ Steven Cyros

II.5. Exploring factors of disaster preparedness in UNESCO-designated heritage sites

Abstract

Increased hazards threatening the United Nations Educational, Scientific and Cultural Organization (UNESCO)-designated sites and endangering cultural heritage and community well-being require attention and action. Considering the pivotal role of UNESCO sites in conservation and development, this study assessed their levels of disaster preparedness. The absence of studies assessing disaster awareness, risk perception, and preparedness among UNESCO site actors, as well as the pivotal place of preparedness within the Disaster Risk Management (DRM) cycle justifies this research. Applying the tenets of the Person-Relative-to-Event framework, we hypothesized that a strong positive correlation exists between perceived risks, resources, and disaster preparedness. To collect pertinent data, we employed an embedded mixed-method design and conducted an online questionnaire survey yielding 141 responses from 59 countries. From the results of relevant analyses, wildfires, floods, and droughts are top hazards occurring frequently in UNESCO sites, with significant concerns about pollution and habitat loss during future events. Smartphones emerged as the most available crucial DRM resource, with higher availability of DRM resources correlating positively and significantly with sites' preparedness. Our findings contribute valuable insights to address missing links for disaster-ready and resilient UNESCO sites, promoting their preservation for future generations.

Keywords: Biosphere Reserves, Disaster risk management (DRM), Global Geoparks, Person-Relative-to-Event framework, Sustainability, World Heritage Sites

Highlights

- Wildfires, floods, and droughts are the most frequently occurring hazards on sites.
- Future disasters will most likely cause pollution from waterborne debris.
- African sites' staff express higher risk perception and vulnerability levels.
- Expansive territory of biosphere reserves obscure DRM coordination mechanisms.
- Disaster awareness and DRM resources are key predictors of preparedness.

II.5.1. Introduction

The occurrence of hazards should not always lead to disasters. However, factors such as vulnerability and lack of coping capacity makes a natural event (i.e., hazard) transition into a disaster, with its severe attendant impacts (Eze and Siegmund, 2024). The United Nations International Strategy for Disaster Reduction (UNISDR, 2009) describes vulnerability as the inherent features that make an asset, community, or system susceptible to damages from a hazard, while presenting coping capacity as the ability of such asset, community, or system to manage adverse situations. The recognition of vulnerability and coping capacity as core components of disasters is necessary to proactively reduce disaster impacts (Raju et al., 2022).

Among previous studies, Cardona et al. (2012) and Ismail-Zadeh (2022) clarified the role of vulnerability and exposure as drivers of disaster with natural hazards only serving as a trigger, and climate change as an intensifier. Furthermore, the studies by Cui et al. (2021) and Titko and Ristvej (2020) recognized the need to manage disasters threatening natural and human infrastructures to achieve sustainable development. Several plans and goals of the United Nations Educational, Scientific and Cultural Organization (UNESCO) cater to risk management within the context of UNESCO-designated sites, which we consider within this study.

Three key site types are designated by UNESCO based on their outstanding natural or cultural values namely global geoparks (GGs), biosphere reserves (BRs) and world heritage properties (WHPs). While GGs and BRs are areas of unique geological and biodiversity conservation landscapes with opportunities for education and research, WHPs are designated for their significant cultural or historical outstanding universal value (Pavlova et al., 2019). As of October 2023, information on various UNESCO websites shows that there are 195 GGs, 748 BRs and 1,199 WHPs in 48, 168, 134 countries, respectively. These UNESCO-designated sites are significant tokens of nature conservation and cultural preservation as a way that both relives history and supports sustainable development.

Specifically, De Silva (2003) argues that such heritages significantly increase the quality of life by transmitting the value and pride of historical messages throughout all civilizations. Therefore, any loss of these heritages (natural and cultural) is inimical to sustainable development as it would divest current and future generations from its rich benefits. In the view of Luo et al. (2022), these sites provide an opportunity for socioeconomic and environmental improvement at several scales, ranging from the local host community to global-level, and advance the achievement of sustainable development goals (SDGs). Thus, the contributions of UNESCO-designated sites as a source of livelihood for host communities as well as being an epitome of civilisation warrant their effective protection from potential threats.

The exposure of UNESCO sites to various hazards, which threaten their continued existence, has been documented in previous research. For example, Pavlova et al. (2017, 2021) estimated over 2,000 sites as exposed to several natural hazards, with over 92% of the sites exposed to at least one main natural hazard. In addition, the study of Sugio (2015) posited that natural hazards, which were increasing in frequency and intensity and were more complex/difficult to predict, caused damage to the inhabitants and ecosystems of UNESCO-designated sites.

Similarly, Valagussa et al. (2021) explained that natural events significantly put pressure on these heritage sites, while Pavlova et al. (2017) maintained that damages on these sites subsequently impacted the lives and livelihoods of surrounding communities who depended on them and could lead to the erosion or total loss of the sites' unique cultural and historical values. Considering the increasing risk of losing our collective heritage, which has been preserved for centuries, due to climate change, it becomes imperative to assess factors of disaster preparedness on these sites.

It is well documented that the management cycle of disasters contains four major stages – preparedness, emergency response, recovery, and reconstruction stages spread within the pre-disaster, during-disaster, and post-disaster phases of a hazard event. In this study, we focus on the preparedness phase of the DRM cycle. According to Shi et al. (2020) preparedness places as the topmost of the four stages of DRM as it focuses on capacity building, disaster response schemes, communication, and education.

Similarly, another study by McNutt (2015) reiterated the need for a concerted effort to improve the preparedness of pre-identified vulnerable communities since natural hazards have become rather frequent. Moreover, Ismail-Zadeh (2020) clarified that preparedness and awareness are significant factors in disaster risk mitigation as they enhance safety during disasters and reduce losses. Therefore, investing in preparedness would minimise losses during the occurrence of hazards.

Studies evaluating the disaster preparedness of UNESCO-designated sites are sparse. Previous studies on this topic showed that disaster threats were acknowledged but not considered a priority among heritage managers (Graham and Spennemann, 2006), while the global geological hazard risk assessment of Pavlova et al. (2017) reported heritage managers' inadequate awareness of appropriate prediction or reaction to selected hazard events. Most recently, Durrant et al. (2023) found WHP managers to have limited access to DRM strategies, practical implementation experience and a poor grasp of a broader range of disaster risks. Also, they opined that the exploration of the roles and perceptions of UNESCO site actors in DRM is an emerging area of research.

Whereas these studies focused on the awareness component of preparedness using different measures, they did not capture other elements such as available resources, site value assessment and disaster experience. Also, human-induced hazards were not captured in these previous studies. Therefore, we adopt a broad conceptual approach in evaluating the disaster preparedness of UNESCO-designated sites to fill these research gaps from previous studies.

The centrality of preparedness and awareness in coping with or reducing disaster impacts necessitates further research. Specifically, Chopra and Venkatesh (2015) postulated that awareness and preparedness are central to capacity building for effective DRM, paving the way for improved resilience. We focus on all UNESCO actors within the three site types as participants of our study, as they are required to champion DRM and resilience initiatives on these sites. Herein, the term UNESCO actors refers to the diverse array of stakeholders actively involved in managing, conserving, and promoting UNESCO-designated sites globally. The methods section provides a more detailed description of these actors. In this study, we assess the levels of disaster awareness, risk perception and preparedness of UNESCO sites to address the preidentified gaps in the literature and to contribute new insights on the topic.

A significant theoretical framework that shapes this study is the person-relative-to-event (PrE) model by Duval and Mulilis (1999). The PrE framework seeks to gauge intentions to prepare for disasters and uses problem-focused coping as its outcome. The model connects people's perception of sufficient resources for dealing with a threat to their engagement in problem-focused coping. Problem-focused coping refers to efforts to manage stressors (Landy et al., 2022). Stressors in the context of this studies will be the hazards or disasters confronting UNESCO actors. Based on this model, we assume that respondents' perception of the adequacy of DRM resources would corelate to their level of preparedness.

The PrE has been used by Mulilis and Duval (1995, 1997), to successfully explain preparedness for natural hazards such as tornadoes and earthquakes. However, in addition to perception of adequate DRM resources, as in the PrE, we include additional variables such as disaster awareness, risk perception, disaster exposure and disaster experience to provide a more robust explanation for and ascertain their combined roles on disaster preparedness by UNESCO actors (Fig. II.5–1). Consequently, we hypothesize that a strong positive correlation exists between higher risk perception, DRM resources and elevated levels of disaster preparedness. The relevance of other variables are briefly presented hereunder.

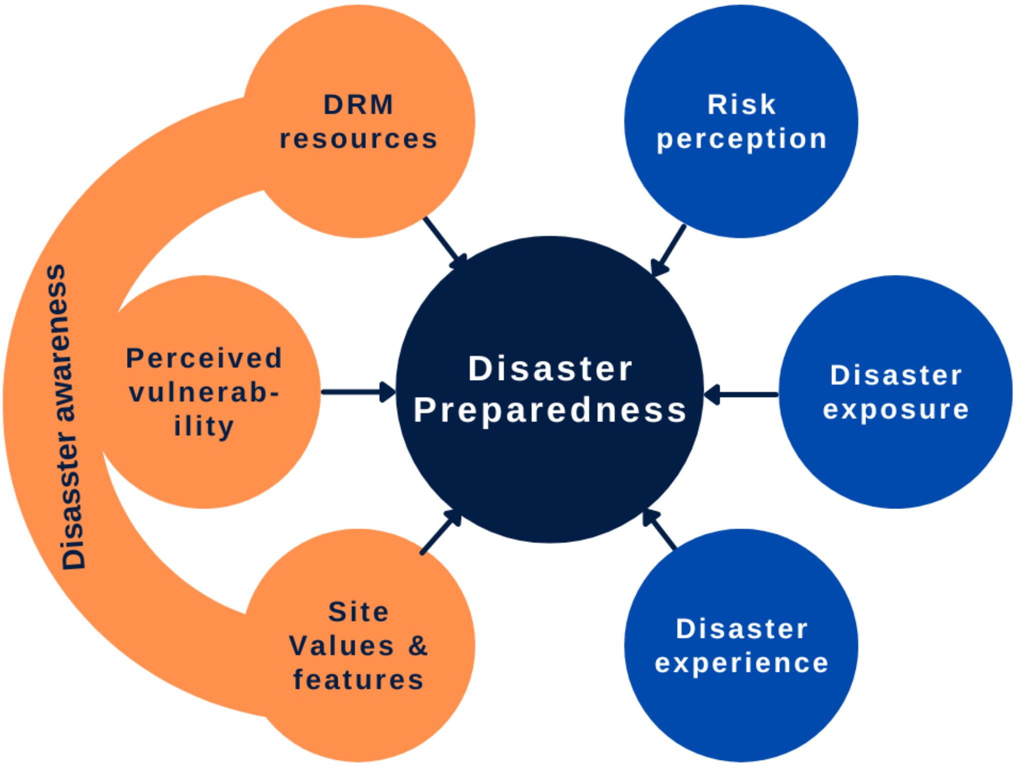

Figure II.5–1: Conceptual model guiding the study.

Figure II.5–1 aligns with Patel et al. (2023) by integrating disaster awareness as a composite measure encompassing respondents' knowledge of their sites' values & features, vulnerability factors, and DRM resources. Also, we consider the findings of Mañez et al. (2016) emphasising the significance of risk perception in enhancing preparedness and reducing vulnerability, while including disaster experience (direct or indirect involvement in past disasters) and disaster exposure (frequency of hazards) as likely factors shaping preparedness, drawing support from studies by Weber et al. (2018) and Yildiz et al. (2023). The interconnections among these concepts have been presented in previous literature.

For example, disaster awareness is described by Patel et al. (2023) as the level of knowledge about disaster factors and potential losses, and how such knowledge influences actions to address vulnerability to hazards. We therefore regard disaster awareness as the collective knowledge of vital information about the outstanding universal value of a site, factors of vulnerability, and DRM-related resources. Disaster awareness is important in building personalised risks, which should be important in disaster risk reduction (DRR) (Gouda and Yang, 2023). Moreover, previous studies have found varying relationships between disaster awareness and preparedness. For example, Rogayan and Dollete (2020) found a moderate relationship between both variables in a Filipino community, while the study of Kang et al. (2023) reported a moderate to low correlation between disaster awareness and preparedness among South Korean nursing students. Moreover, we have included the concept of risk perception to warrant robust findings and contributions to the discourse.

Generally, the literature portrays risk perception as having two dimensions – the cognitive and emotional dimensions. For example, Paek and Hove (2017) depict cognitive risk perception as how much understanding of risks people possess, while the emotional dimension covers the feelings of people towards risks. A simplified description of these two dimensions of risk perception is couched by Lechowska (2018) as awareness and worry, respectively. This study is delimited to the cognitive dimension of risk perception. A primary justification to consider risk perception is drawn from the study of Mañez et al. (2016) who identified it as crucial in the determination of the impact of risk management and vulnerability reduction initiatives.

Moreover, risk perception has been connected to sustainability in a recent study by Billman et al. (2023). They specify that a shift in risk perception is needed to integrate sustainable practices to give precedence to long-term risk reduction efforts. Another study by Alam (2016) reported a strong relationship and causation links between risk perception and disaster preparedness, with mediation effects from direct disaster experience. Hence, understanding the risk perception levels of UNESCO actors could unveil their actions in response to risks, and such information, according to Gough (1990), could be useful for enhancing risk communication, and for the prediction of risk-reduction behaviours such as preparedness (Anderson et al., 2023). The present study is therefore poised to determine the relationship and links between disaster awareness, risk perception, disaster experience and disaster preparedness.

Furthermore, the role of previous disaster experience on preparedness is included in the study due to an absence of consensus in the literature. For example, studies by Weber et al. (2018) and Yildiz et al. (2023) show disaster experiences as reinforcement of risk perception as a personal threat, ultimately leading to enhanced preparedness. Conversely, disaster experience (i.e., whether a person is directly involved, or indirectly from others' accounts) does not always lead to preparedness, as Becker et al. (2013) assert that direct losses from disaster experiences more significantly drive preparedness than indirect experiences. Therefore, we consider the role of direct and indirect disaster experiences on disaster preparedness among UNESCO actors.

The UNISDR (2009) defines disaster preparedness as incorporating knowledge and capacities, which are developed while expecting disasters to effectively respond to or recover from their impacts. This phenomenon may bring the need for contingency plans, coordination, evacuation and public information, simulations and stockpiling of equipment to indicate disaster preparedness and readiness. Similarly, Nikkanen et al. (2023) capture several factors of preparedness such as personal characteristics, socioeconomic factors, risk perception and previous experiences with disasters. The state of disaster preparedness, where UNESCO sites can promptly and appropriately respond to a hazardous event, is largely unknown. Two aspects of preparedness (i.e., DRM resources for emergency provisions available and hazards preparedness) were assessed in this study. However, where the concept of disaster preparedness is used, DRM resources for emergency provisions are implied.

The results of this study will provide insights into disaster preparedness in UNESCO sites. In the view of Thomas et al. (2015), knowledge of disaster preparedness should be captured for effective communication and campaigns on the subject. Hence, this study has multifaceted contributions to DRM, nature and cultural conservation, capacity building, and sustainability. By providing information on frequently occurring natural and man-made hazards and vulnerability factors, the study lays a good foundation for crafting targeted and effective DRM strategies.

Conservation efforts can be tailored to mitigate specific risks identified in the study, ensuring the long-term sustainability of UNESCO-designated sites. Highlighting the availability of DRM resources in sites can be instrumental to the design of suitable educational interventions or capacity-building programs for host communities and managers of these sites to address specific gaps and empower local communities and institutions for resilience to disasters. Ultimately, the creation of resilient communities translates to the sustainability of UNESCO sites, preserving these natural and cultural heritage for future generations.

This study, therefore, focuses on answering the overarching question 'Among disaster awareness, and risk perception held by key UNESCO site actors, what factors be enhanced to promote efficient disaster preparedness and risk management within UNESCO-designated sites?'

Specific objectives to be pursued within the study will answer the following questions:

1. What are the levels of disaster awareness, disaster experience, risk perception and disaster preparedness among UNESCO site actors in GGs, BRs, and WHPs?
2. What are the relationships between disaster awareness, disaster experience, risk perception and disaster preparedness among UNESCO site actors in GGs, BRs, and WHPs?
3. What strategies can be recommended to improve DRM practices and enhance resilience within UNESCO-designated sites?

II.5.2. Methods

II.5.2.1. Design of the study

This study employed an embedded mixed-method research design, integrating both quantitative and qualitative data sources. This method was used because it could seamlessly incorporate qualitative elements into a quantitative research framework or vice-versa and offers a valuable approach for simultaneous data collection (Creswell, 2014). An online survey was designed and deployed in Survey Monkey to obtain responses from UNESCO actors used for this study. A total of 14 items in the survey are used for this paper. Responses regarding disaster exposure, risk perception, and disaster awareness were gathered through a rating scale.

In this study, we took an innovative approach by appending options for additional comments to all question items, including Likert-type, checkbox, and yes/no question types, to elicit further insights from respondents (Supplementary material S1). The inclusion of open-ended comment boxes served to solicit additional perspectives within the survey responses, enhancing the depth of the data collected. Researchers often opt for embedded methods for different reasons, nevertheless, it is applied in this study to facilitate a more comprehensive understanding of participants' viewpoints, especially regarding their disaster experiences.

For disaster exposure data, respondents selected the frequency level for each hazard, ranging from 0 for "Not relevant/cannot occur on my site location" to 6 for "Frequently–more than once in 5 years." Similarly, the likelihood of damages from future disasters was rated on a scale from 1 for "Extremely unlikely" to 5 for "Extremely likely." Disaster awareness was evaluated using essential risk assessment items for UNESCO-designated sites, categorized from 0 for "Not at all aware" to 4 for "Extremely aware."

The questionnaire encompassed various elements for assessing variables like DRM resources, perceived vulnerability, and hazard preparedness utilized a checklist question format. Meanwhile, disaster experience and site preparation were structured as Yes/No questions. Each query included an 'other' option allowing respondents to share additional personal experiences beyond the provided item lists (Supplementary material S1).

II.5.2.2. Participants of this study

Participants of this study are UNESCO actors. The participants in our study, termed as UNESCO actors, encompass individuals from diverse backgrounds and roles, including members of UNESCO national commissions worldwide and personnel directly involved with managing and overseeing UNESCO-designated sites. These individuals hold significant responsibilities spanning site management, conservation, educational, policy enactment, and research initiatives within these locations. Our research places emphasis on UNESCO actors as the primary respondents, valuing their unique insights, extensive experiences, and viewpoints concerning disaster risk management within these sites.

We utilized a combined sampling approach involving harvested email lists (Fricker, 2008) and river sampling (Lehdonvirta et al., 2021) for our research, both belonging to the convenience non-probability sampling method. Harvested email lists encompass email addresses sourced from various online platforms, while river sampling involves inviting respondents from a specific population to partake in a survey through links placed on websites or emails. In our study, we collected UNESCO actors' email addresses available online and disseminated our survey via email. However, both sampling methods limit the generalizability of our findings solely to active respondents, which suggests coverage bias (Lehdonvirta et al., 2021). This bias stems from disparities in internet access, usage patterns, and visit frequencies (Van Dijk, 2005). We distributed our online survey to 1,009 professional email addresses of UNESCO site actors in two primary phases: from August 2022 to February 2023 and from September to October 2023.

To enhance response rates, the survey was circulated multiple times. Reminders were sent in October and November 2022, as well as in February 2023 during the first phase. In the second phase, reminders were dispatched after the fourth and fifth weeks. Despite these efforts, the response rate stood at 13.98%, with 141 received responses. It is noteworthy that these responses represented approximately 59 countries, offering a diverse perspective across various sites, continents, and contexts. While the response rate was modest, the findings, although not entirely representative, provide valuable insights for the initial exploration of disaster awareness, experiences, preparedness, risk perception, DRM resources, and perceived vulnerability among UNESCO actors. Considering the demanding work schedules of respondents, the arguments posited by Pharaoh and Visser (2023) could be valid. They suggest that an excessively surveyed population may encounter survey fatigue, leading to reluctance in responding to what they view as 'non-essential' surveys (Pharaoh and Visser, 2023).

Within our study, the responding UNESCO actors were affiliated with various types of designated sites, including World Heritage Sites (n = 27), Biosphere Reserves (n = 101), one Global Geopark, and a few categorized under 'Others' (n = 7). Participants falling under the 'Others' category identified themselves as staff members of UNESCO national commissions, Ramsar sites, national parks, and heritage sites currently being considered for UNESCO designation. This diverse pool of respondents represents approximately 59 countries across the globe. Further details regarding the respondents' countries of origin, length of service, educational qualifications, gender, and age are provided in Supplementary material S2.

II.5.2.3. Questionnaire development, validation, pretest and reliability

Before this research, we were unaware of any survey reportedly measuring similar variables. Therefore, a questionnaire was developed with items drawn from various sources (See supplementary material S1). A list of natural hazards was drawn from the classifications of the Emergency Events Database (EMDAT) (2022) based on Below et al. (2009), to determine disaster exposure in this study. Of the six classes of natural hazards, four classes were of interest, namely: geophysical, hydrological, meteorological, and climatological hazards.

In addition to natural hazards, 'violent conflicts' was included as an item of the listed hazards for consideration, in line with the suggestions of Eze and Siegmund (2024) to incorporate anthropogenic hazard dimensions in risk assessments. While items to determine risk perception, disaster awareness and preparedness items were adapted from UNESCO, ICOMOS & IUCN (2010), items that made up the DRM resources, vulnerability and disaster experiences components were drawn from various literature sources on the topic.

As a newly compiled research instrument, expert validation and pilot testing were necessary to identify ambiguously formulated items. Thus, the designed questionnaire first underwent face validity. Professors, postdoctoral researchers and doctoral students in the Department of Geography, Heidelberg University of Education, Germany, were invited to check the wording of the questionnaire items for relevance, clarity, and suitability in answering the set research questions. Six persons, including one professor, and five doctoral researchers gave suggestions that were incorporated into the final version. As part of their comments, inclusion, modification, and removal of some items were made to improve the clarity of the final version.

For example, hazard items of the questionnaire such as volcanic activity: ash fall, volcanic activity: lahar, volcanic activity: pyroclastic flow, and volcanic activity: lava flow were represented with 'volcanic activity' in the final questionnaire. Similarly, the various flood types initially listed as flood: coastal flood, flood: riverine flood, flood: flash flood, and flood: ice jam flood are compressed simply as 'flood'. Also, the item 'destructive wave actions' in the final questionnaire was merged from two items – wave action: rogue wave and wave action: seiche. Vocabulary changes to improve item clarity, such as changing 'fog' to 'dense fog'; "looting of cultural artifacts on the site artefacts" to "stealing of cultural artifacts on the site"; unregulated land use planning to 'poor land use planning'; 'someone close to you' was replaced with 'someone you know' in items 11, 12 and 13 of the final questionnaire. Also, in line a validator's comment, the survey was machine-translated from English to other UNESCO languages (Arabic, Chinese, French, Portuguese, Russian and Spanish) and checked by native speakers of the respective languages before circulation.

Secondly, a pilot study to pre-test the developed questionnaire was conducted among selected respondents in European UNESCO sites, especially biosphere reserves, which yielded 41 responses. We focused on European biosphere reserves for the pre-test of our questionnaire in line with our choice of sampling techniques (i.e., harvested email lists and river sampling). This decision was primarily influenced by our access to a comprehensive and easily accessible list of email addresses online.

A test for the internal consistency of the responses was conducted. The Cronbach Alpha results obtained were 0.848, 0.865, and 0.949 for the responses of disaster exposure, risk perception, and disaster awareness, respectively. These results indicate a high level of internal consistency (> 84%) of all the item clusters in the questionnaire. Upon the analyses of the entire responses (n = 141), the reliability results maintained a high level of consistency for items of disaster exposure, risk perception, and disaster awareness with Alpha results of 0.809, 0.906, and 0.954, respectively.

II.5.2.4. Data analyses

We analysed survey responses using IBM SPSS Statistics (Version 29). The variables in the study are presented in Table II.5–1.

Table II.5–1: Variables used in the study

Variable name	Variable type and role
Hazard frequency	• Mean rating of item 7 of the questionnaire • Independent variable in stepwise regression analyses
Risk perception	• Mean rating of item 8 of the questionnaire • Independent variable in stepwise regression analyses
DRM resources	• Sum of checklist responses to item 9 of the questionnaire • Independent variable in stepwise regression
Vulnerability conditions	• Sum of checklist responses to item 10 of the questionnaire • Independent variable in stepwise regression analyses
Disaster experiences	• Sum of responses to items 11–14 of the questionnaire • Independent variable in stepwise regression analyses
Disaster awareness	• Mean rating of item 15 of the questionnaire • Independent variable in stepwise regression analyses
Site preparedness	• Sum of responses to item 16 of the questionnaire • Dependent variable in stepwise regression analyses
Hazards preparedness	• Sum of checklist responses to item 17 of the questionnaire • Independent variable in stepwise regression analyses

Note:
All variables are used for descriptive analyses, mean significance tests, correlation analyses and stepwise regression analyses to obtain the results of this study.

In this study, various statistical techniques were applied to comprehensively analyse and interpret the collected data. To initially gain an understanding of the sample characteristics, descriptive statistics were employed. These statistics, including frequencies, mean, and standard deviation, provide a summary of the responses from all the tested variables (Table II.5–1). We further investigated differences in responses based on all variables in the study using independent t-tests and one-way analysis of variance (ANOVA) to ascertain potential disparities or similarities among distinct groups of respondents. These inferential statistical tests were instrumental in examining whether there were significant differences based on the job roles, site types, and site locations of responding UNESCO actors.

Moreover, correlation tests were conducted to explore the relationships among the variables in this study and identify potential patterns or connections between them. To extend the findings from the correlation tests a stepwise regression analysis was performed. The stepwise regression is a statistical method used to select the most significant predictors among several variables, while exempting variables of high multicollinearity (variance inflation factor—VIF) in its results (Eze et al., 2022). We adopted this technique due to its usefulness in identifying variables with the strongest impact or contribution to the outcome variable, which, in this study, is site preparedness. All analyses were conducted at the conventional threshold of $p < 0.05$.

II.5.3. Results

Results of the levels of and interrelationships among disaster exposure, risk perception, available DRM resources, Perceived vulnerability, disaster experience, awareness, and preparedness are hereunder presented.

II.5.3.1. Disaster exposure

Over half of the respondents identified forest fire, land fire, flood, drought, dense fog, and extreme heat wave as top frequently occurring hazards (Table II.5–2). From the rating frequency, 78 % of respondents indicate that forest fires are the most frequently occurring hazards ($\bar{X} = 4.36$, SD = 1.89), while glacial lake outbursts are rated the least occurring ($\bar{X} = 0.52$, SD = 0.92). Other frequent hazards, albeit man-made, not captured in the listing included by respondents are red tides and oil spillage. Some other respondents consider deforestation and poaching as additional ‘hazards’ worthy of mention.

Table II.5–2: Frequency of hazards

Hazards	Rarely occurring (%)	Frequently occurring (%)	Mean	Std. Deviation
Ground movement (Earthquake)	58.9	41.1	2.65	2.17
Tsunami	65.0	3.6	0.81	1.13
Rockfall	58.7	41.3	2.66	2.29
Landslide (dry)	63.7	36.3	2.43	1.98
Landslide (avalanche of snow, debris, or mudflow)	68.9	31.1	2.22	2.10
Volcanic activity	85.4	14.6	1.09	1.70
Extreme cold wave	69.2	30.8	2.21	1.89
Extreme heatwave*	40.9	59.1	3.40	2.22
Severe winter conditions	33.6	31.4	2.93	2.09
Dense Fog*	36.7	63.3	3.70	2.24
Extra-tropical storms e.g., cyclones, blizzards	41.6	24.1	2.27	2.31
Tropical storms e.g., hurricanes	47.4	19.0	1.86	2.19
Convective storms e.g., tornadoes	67.4	32.6	2.10	2.02
Flood*	28.3	71.7	4.07	2.00
Destructive wave actions	44.5	21.2	2.09	2.13
Drought*	32.6	67.4	3.89	2.08
Glacial Lake Outburst	96.6	3.4	0.52	0.92
Forest Fire*	21.7	78.3	4.36	1.89
Land fire of Brush/bush/Pasture*	23.9	76.1	4.33	1.99
Violent conflicts/riots/unrest/protest	71.4	28.6	1.93	2.02
Cluster mean			2.58	

N=141 | *Frequency and mean ratings greater than 50%

More respondents from BRs reported frequent occurrences of severe winter conditions on their sites compared to those from WHS. However, over half of the respondents from both WHS and BR indicated frequent occurrences of extra-tropical storms, destructive wave actions, glacial lake outbursts, land fires, and violent conflicts in their sites (Table II.5–S1). In addition, responses from UNESCO actors across continents reveals that destructive wave actions, glacial lake outbursts, land fires, and violent conflicts are frequently occurring hazards within UNESCO-designated sites globally, spanning Africa, Asia, Europe, North America, Oceania, and South America. Among these regions, African UNESCO actors reported the least number of frequently occurring hazards, citing three out of twenty, while Asian respondents documented the highest number of frequent hazards, indicating ten out of twenty (Table II.5–S2).

II.5.3.2. Risk perception

Responses contained in Table II.5–3 show that most of the listed impacts are unlikely to occur during future disaster events. However, four likely impacts stood out, which includes pollution, degradation of the outstanding/unique universal value of the property through habitat loss, poaching or emergency response activities, and loss of livelihoods associated with the property. These impacts are likely to occur both in WHS and BR. Detailed results of responses based on site types are presented in the Supplementary Table II.5–S3.

Table II.5–3: Likely impact of future occurrence of disasters on or around UNESCO sites

Items	Unlikely (%)	Neutral (%)	Likely (%)	Mean	Std. Deviation
Damage to the property's outstanding universal value during emergency response activities.	33.7	26.3	40.0[W,B]	3.01	1.19
Damage or pressure caused by displaced peoples, particularly regarding camps of displaced peoples, their associated infrastructure and their waste and energy requirements.	44.2	21.1	34.7[W,B]	2.65	1.25
Encroachment of people into the site	41.1	24.2	34.7[W]	2.83	1.23
Pressure of development and illegal or uncontrolled development.	38.9	23.2	37.9[W,B]	2.92	1.30
Injury, mortality, or displacement of staff that can reduce the capacity for security, monitoring and enforcement.	40.0	27.4	32.6[W]	2.78	1.23

Loss of livelihood sources linked to the property.	34.7	24.2	41.1 [W,B]	3.00	1.24
Stealing of cultural artefacts on the site	63.2	16.8	20.0 [W]	2.20	1.23
Enhanced rate of deterioration of damaged wood or stone.	38.9	22.1	38.9 [W,B]	2.91	1.15
Risk of the loss of authenticity or falsification through reconstruction.	47.4	26.3	26.3 [W]	2.54	1.19
Water damage from firefighting.	45.3	23.2	31.6	2.65	1.22
Unique universal value and integrity are degraded through habitat loss and poaching.	40.0	11.6	48.4 [W,B]	3.03	1.32
Pollution from waterborne debris and contaminated watercourses.	31.6	13.7	43.2 [W,B]	3.20	1.28
Damage to site-level office buildings and equipment	37.9	25.3	36.8 [W]	2.92	1.16
Hazard-specific risks affect site-level staff	43.2	25.3	31.6 [W]	2.74	1.18
Hurricanes and tornadoes can lead to storm surges, which can cause flooding.	64.2	12.6	23.2 [W]	2.18	1.40
Earthquakes on my site may cause a tsunami, fire, and landslides	71.6	13.7	14.2	1.98	1.18
Cluster mean				**2.47**	

Notes:
[W,B] Impacts confirmed by at least a third of respondents from: W = WHS; B = BRs | n =141

II.5.3.3. Available DRM resources

This study identifies resources (un)available for DRM in UNESCO-designated sites. From Figure II.5–2, only smartphone was rated as available by more than half of the study's respondents, while pagers/beepers were the least available. From other additional comments received, other institutional arrangements such as municipalities, and government agencies in charge of civil protection and emergency response are saddled with disaster preparation and response equipment.

For example, a respondent writes that "these resources are managed and offered by governments in the event of disasters or other situations. The biosphere reserve's representative does not have these resources in-house." Other similar responses stated that "...other agencies have specific responsibilities for fire, wind issues etc."

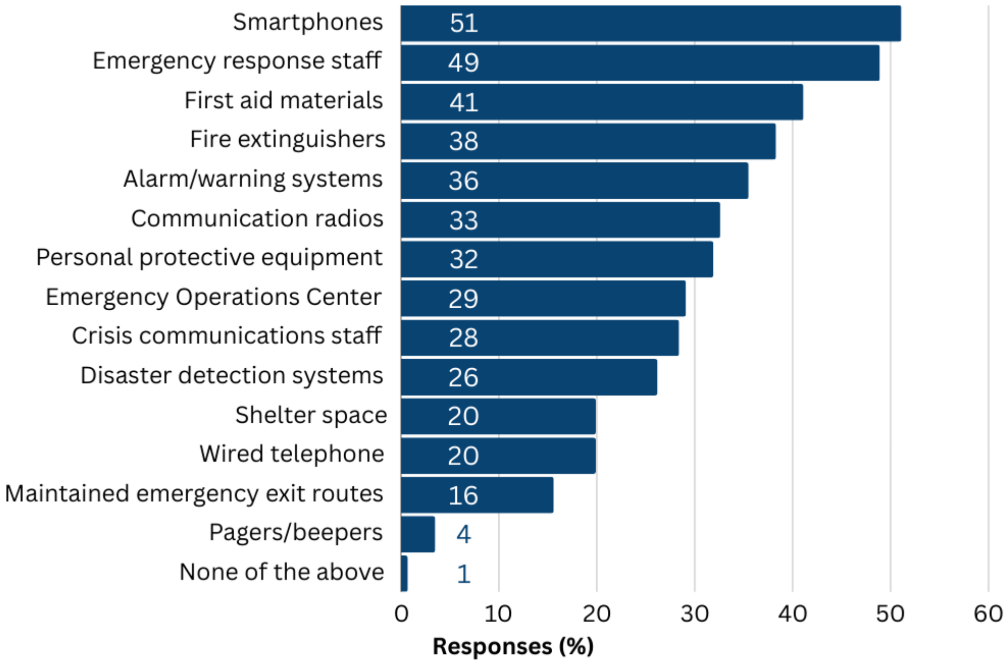

Figure II.5–2: Skills and resources available for use in managing adverse conditions, risks, or disasters on UNESCO sites | n =141

II.5.3.4. Perceived vulnerability

None of the items related to vulnerability were rated by over half of the respondents. Half of the respondents rated climate change as a significant factor of vulnerability. Also, poor environmental management were selected by a substantial number of UNESCO site actors as vulnerability factors (Figure 3).

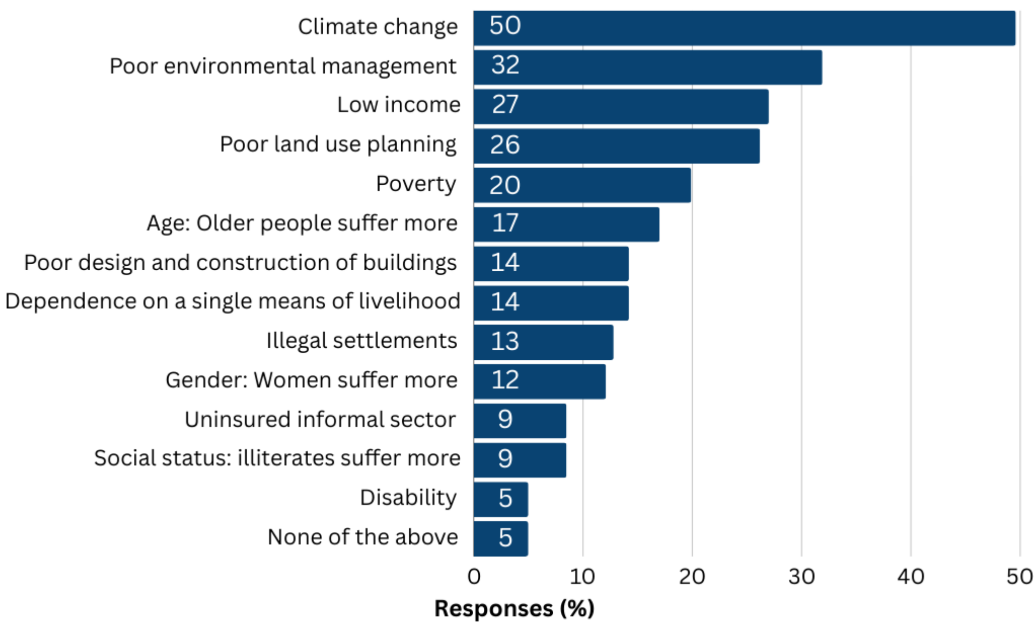

Figure II.5–3: Conditions that make UNESCO sites and their residents easily affected by the occurrence of a disaster | n =141

II.5.3.5. Disaster experience

Respondents expressed different levels of direct (i.e., personal), and indirect (i.e., other's) disaster experiences and damages (Figure II.5–4). Additional comments from respondents point to experiences of losses due to grass fires, flooding, and volcanic eruptions. Physical harms in the form of fatalities, damaged homes and livelihoods, restricted access to basic services, and health issues like burns and smoke inhalation were specified by respondents. For example, one of the comments reads "In 2010 the fires were very close to my camp where I lived and worked, we ran out and everything was on fire and we had to go to the river to take shelter."

Furthermore, 23 respondents in this study gave brief comments on the profound emotional harm directly or indirectly endured during past disasters. Each of the words 'trauma', 'suffer', and 'stress' were used three times. The loss of property, poverty, and the fear of river floods contribute to depression and stress within communities, with a higher impact on the elderly. Disappearance of family or community members seemed to intensify emotional devastation and trauma. One of the respondents shared a personal comment: "Fires always affect people emotionally and I have trauma that I carry from many events related to fires in which we have had to fight day and week; very large fires where we see many wild animals suffer and die." Another participant confirmed the source of their response in the following exact words: "I interviewed residents of an old age housing complex after a severe flood and the trauma they experienced was expressed."

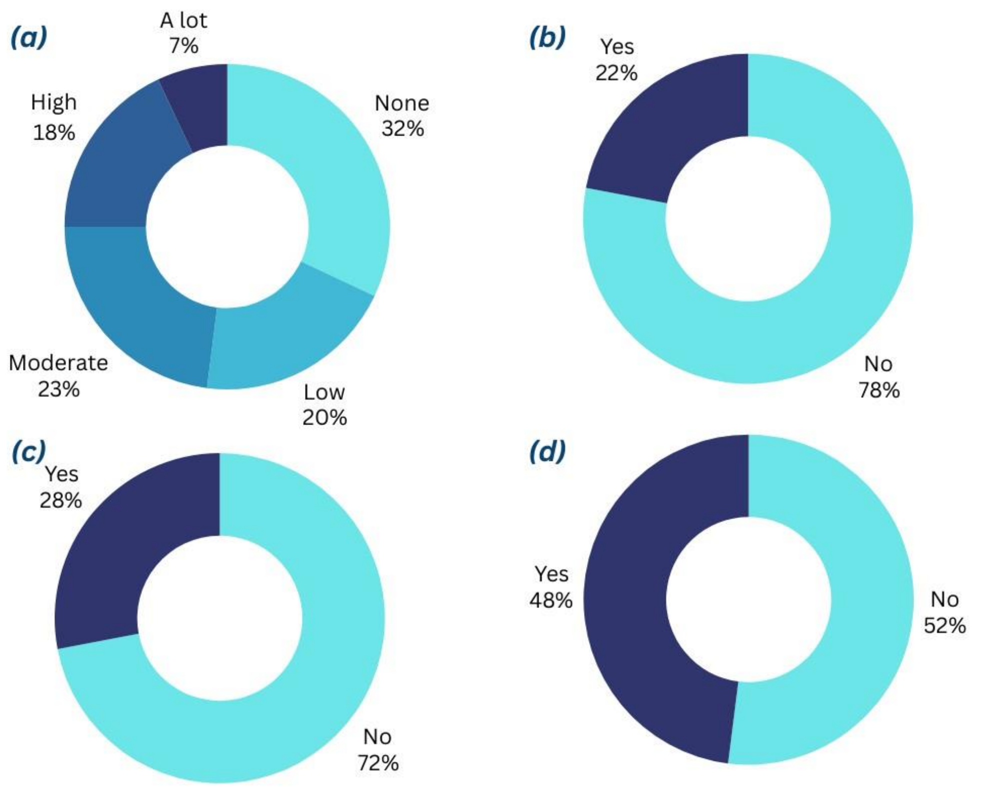

Figure II.5–4: Direct and indirect experiences with past disasters: (a) Damages from a past disaster (b) Physical harm from a past disaster (c) Emotional harm from a past disaster (d) Experience with frightening natural events | n =141

About 48% of the participants in this study have witnessed frightening natural events that did not cause them any harm or damage. More than 30 of them gave further insights into these events. Four events are recurring among respondents namely fire (n=16), flood (n=7), rain (n=6) and storms (n=5). A participant recalls that "a fire that almost burnt down my house made me aware of how vulnerable we are to fire."

II.5.3.6. Disaster awareness

Awareness of all listed items in Table II.5–4 was highly rated by most participants in the study. The item with the highest awareness and mean rating was the attributes that carry the outstanding universal value and justify the criteria for inscription of the property on the UNESCO cultural/biosphere Heritage list.

Table II.5–4: Level of awareness of items essential for disaster risk assessment

Items	Low (%)	High (%)	Mean	Std. Deviation
The attributes that carry the outstanding universal value and justify the criteria for inscription of the property on the UNESCO cultural/biosphere Heritage List	17.3	82.7	4.28	0.98
A list of factors and processes that will lead to damage or deterioration in the event of disaster occurrence	36.0	64.0	3.80	1.14
Geographical information on the location of the property, its boundaries, its buffer zone, its immediate surroundings, access, topography, and others	21.3	78.8	4.28	0.91
Geological information on the nature of the soil and fault lines (if any)	37.8	62.2	3.59	1.08
Hydrological information on the water table, surface water such as rivers and others	28.4	71.6	3.88	1.05
Meteorological information on the nature of the climate	29.3	70.7	3.88	1.00
Thematic maps of the area or region in which the property is located, such as a hazard vulnerability map	37.3	62.7	3.67	1.07
Information on the history of different disasters affecting the area or the property itself	40.0	60.0	3.55	1.11
Inventories and the status of existing management systems and disaster preparedness equipment and facilities in the property, such as for shelter, evacuation, and rescue	54.1	45.9	3.32	1.14
Evaluation of hazard-specific equipment and needs e.g., the different needs for floods, fires,	62.5	37.5	3.08	1.18

landslides, pollution events and disease epidemics				
Existing relevant institutions within the site	33.8	66.2	3.84	1.15
Existing community around the site	32.5	67.5	4.05	1.05
Physical planning (land use, transport and infrastructure) of the area in which the site is located	40.0	60.0	3.77	0.96
Condition of roads for potential evacuation during a disaster	35.6	64.4	3.68	1.14
Local and traditional knowledge systems relevant to disaster risk reduction	47.9	52.1	3.55	1.14
Complete and easily accessible directory of agencies that will act during disasters	48.8	51.3	3.51	1.27
Cluster mean			3.73	

II.5.3.7. Disaster preparedness

Results of the two aspects of preparedness (i.e., emergency provisions available and hazards preparedness) assessed in this study are presented.

II.5.3.7.1. Emergency provisions on sites

The first part, which relates to emergency provisions within the UNESCO-designated sites indicates a lack of alarm systems, special security cordons, and sufficient communication of emergency plans to staff, residents and visitors (Table II.5–5). However, some respondents who are biosphere reserve staff members clarified that “It's difficult to have all this in place, given that our territory is 7,400km square”; “Since the biosphere is a region, site-specific contingencies that apply to a building or cluster of buildings do not apply”.

Table II.5–5: Emergency provisions in place on sites

Items	No (%)	Yes (%)
A well-developed plan and procedures for evacuating people is available	44.2	55.8
General emergency equipment is installed	41.6	58.4
A comprehensive strategy based on the main risks, the location of the property, and available resources and expertise is formulated	44.2	55.8
Alarm systems, special security cordons	63.6	36.4
Coordination between the site staff and security	33.8	66.2
Maps of the property showing specific features such as utility mains, fire exits, fire extinguishers, and others	42.9	57.1
Communication of the emergency plan and procedures to visitors, staff and local residents by easily readable handbooks, manuals, drawings, and signage	53.2	46.8
Organizing awareness-raising activities such as seminars and exhibitions	46.8	53.2
Training and capacity-building on the use of emergency equipment such as fire extinguishers	40.0	60.0
Regular emergency simulation drills in cooperation with external agencies such as fire services	48.7	51.3

II.5.3.7.2. Hazards preparedness

Secondly, preparedness towards selected hazards in earlier sections of the manuscript were rated in the subsequent portion of the survey. The hazards that participants rated as prepared coincide with frequently occurring hazards (R = .867, $p = <.001$).

Hence, the higher the frequency of hazards, the higher the number of participants that rated prepared for the specific hazard. From the results of disaster exposure, forest fire, land fire, flood, drought, dense fog, and extreme heat waves were identified as the most frequently occurring hazards, while sites are prepared for forest fire, flood, land fire of brush/bush/pasture, extreme heatwave, and dense fog (Table II.5–6).

Table II.5–6: Hazards UNESCO sites are prepared for

Hazards	Responses (%)
Forest Fire	33.3
Flood	26.2
Land fire of Brush/bush/Pasture	24.8
Extreme heat wave	14.2
Dense Fog	14.2
Ground movement (Earthquake)	12.1
Drought	12.1
Severe winter conditions	11.3
Tropical storms e.g., hurricanes	10.6
Rockfall	9.2
Extra-tropical storms e.g., cyclones, blizzards	7.8
Landslide (avalanche of snow, debris, or mudflow)	7.1
Extreme cold wave	7.1
Landslide (dry)	6.4
Convective storms e.g., tornadoes	6.4
Destructive wave actions	6.4
Volcanic activity	5.0
Tsunami	2.1
Glacial Lake Outburst	0.0
Violent conflicts/wars/riots/unrest/protest	0.0
None of the above	4.3

II.5.3.8. Relationships between tested variables

Notable differences in mean scores are observed among various levels of the three examined respondents' characteristics – site type, site location, and job status (Supplementary Table II.5–S4). Regarding disaster awareness levels, a significant variation is evident based on site type, with respondents affiliated with world heritage sites exhibiting the highest levels of awareness. Additionally, individuals from other categories, such as UNESCO national commissions and focal points, demonstrated notably higher levels of disaster awareness and experiences compared to UNESCO site managers and staff. Moreover, respondents from African sites notably expressed higher levels of risk perception and vulnerability in comparison to their counterparts from other geographical regions. This regional disparity suggests a significant divergence in risk perception and vulnerability across different parts of the world.

Additional test results revealing associations among various variables tested, including disaster awareness, hazard frequency, risk perception, DRM resources, vulnerability conditions, disaster experiences, site preparedness, and hazards preparedness (Supplementary Table II.5–S5). Notably, a substantial correlation was observed between hazard preparedness and DRM resources (R = .480, $p < .001$), indicating a significant positive relationship. Furthermore, the results from the stepwise regression analysis (Supplementary Table II.5–S6) demonstrated that among these variables, disaster awareness and DRM skills and resources collectively emerged as the most influential predictors of sites' disaster preparedness ($R^2 = .208$, $p < .001$). These results validate and extend the framework of the PrE model that underpinned our study, and confirm our initial hypothesis.

II.5.4. Discussion

II.5.4.1. Disaster risk exposure, awareness, and experience of UNESCO site managers

The study aimed to explore DRM in UNESCO-designated sites, investigating disaster exposure, awareness, and experience, risk perception, DRM resources, vulnerability, and disaster preparedness. Wildfires, floods, droughts, dense fog, and extreme heat waves are the most frequently occurring hazards, which represents a collective recognition of the diverse threats faced by UNESCO-designated sites. These hazards are of prevalent concern and align with global trends of frequently occurring and highly impactful hazards, such as those listed by Mokhtari et al. (2023).

According to the findings of a systematic literature review on floods in BRs, Eze and Siegmund (2023) posit that the exposure of UNESCO sites to hazards is still understudied. However, a few studies present relatable findings. For example, Porrini and De Masi (2021) identified extreme weather events and floods as impacting heritage sites globally. Also, Durrant et al. (2023) confirm flooding, cyclones and storms as top hazards occurring within WHS in Europe. Similarly, a study in Turkey by Gürsoy (2019) shows the exposure of a site to floods and fires among other hazards.

Conversely, the relatively lower ranking of hazards like glacial lake outbursts suggests the region-specific nature of certain risks. This variability in susceptibility to hazards is influenced by diverse factors including site type, location, and other relevant factors. Hence, risk management strategies should be tailored to specific environmental contexts. Geographical contexts, according to Zuccaro et al. (2020), are crucial to ensure that local knowledge and identity values are incorporated into contextualised DRM policies and strategies. Despite the consideration of site location as a variable, we were unable to conduct a more extensive geographical analyses due to data limitations.

The heightened awareness of the attributes justifying the UNESCO cultural/biosphere heritage list inscription and other necessary information that enhances risk assessment is encouraging. However, it prompts a reflection on the translation of awareness into actionable measures for safeguarding these invaluable sites. Cardona et al. (2012) posit that DRR relies on a well-informed and motivated population, who are prepared by collecting and disseminating relevant information on hazards, vulnerabilities, and capacities. Since most respondents had indicated direct or indirect disaster experiences, it was an unexpected finding to see disaster experience being poorly associated with awareness in the study.

Hence, increased awareness cannot be attributed to disaster experiences in this study. Recognizing the emotional distress experienced by respondents in areas prone to frequent disasters, we recommend the establishment of emotional well-being and trauma support mechanisms for affected communities and staff. This involves acknowledging and addressing the emotional toll of disasters, with the establishment of counselling services and support programs. Should these be available responses like "Fires always affect people emotionally and I have trauma that I carry from many events related to fires…" can be avoided.

The items of the questionnaire used to assess awareness are informative materials and could contribute to high awareness levels because they were extracted and modified from a report of UNESCO, ICOMOS & IUCN (2010). Direct access and interaction or exposure to this document could explain why UNESCO national commissions and focal points exhibit significantly higher disaster awareness levels than site staff. Although, awareness in the context of this study is not related to risk perception, there is a crucial need for targeted awareness programs to bridge existing knowledge gaps among UNESCO site actors.

We suggest that these programs should extend beyond global or regional platforms and include regular national forums dedicated to sharing information on best practices in disaster risk management. The participation of relevant stakeholders in these forums should be made mandatory to cultivate collaboration, facilitate knowledge exchange, and foster capacity building. Furthermore, awareness campaigns must reach down to the community level, ensuring that residents living within these UNESCO sites are well-informed and engaged in disaster preparedness efforts.

II.5.4.2. Risk perception of UNESCO site managers

Participants of this study perceive the likelihood of pollution, degradation of the property's outstanding/unique universal value through habitat loss, poaching or emergency response activities, and loss of livelihoods associated with the property as consequences of future disasters. Our findings contrast with the report by Pavlova et al. (2017) suggesting insufficient awareness of site managers regarding the actual disaster risks faced by their sites. These findings underscore the need for a holistic and sustainable approach to managing these sites.

Moreso, in these times when climate change accelerates the physical, chemical, and biological mechanisms that contribute to material destruction in WHS (Vyshkvarkova and Sukhonos, 2023), conservation efforts must be balanced with community well-being, and emergency responses to ensure the sustainability of these valuable and unique properties. Whereas respondents from African sites express significantly higher risk perception, factors influencing risk perceptions, such as cultural contexts and local experiences, are not covered by this study and merit exploration. Also, insufficient data limits our explanation of these findings.

II.5.4.3. Reported vulnerability of UNESCO sites to disasters

Climate change and poor environmental management emerge as notable vulnerability factors for a substantial number of UNESCO site actors indicating broad systemic challenges. Similar results from Falk and Hagsten (2023) show climate change and local conditions are significant vulnerability factors in WHS management. Also, Durrant et al. (2023) recognise climate change as an irrefutable risk to WHS, but their survey reveals the prioritisation of other anthropogenic vulnerability factors such as land use change, land pressure, and urban development among others. Again, recognition and addressing of sites' vulnerability should be localised. For example, the features of each GG, BR and WHS are unique, implying variations in materials and landscapes in various locations. Contextualised interventions are further necessary as this study finds respondents from African sites, though fewer in number, had a significantly higher vulnerability rating.

It is noteworthy that deforestation, inappropriate irrigation, pollution, unsustainable resource use, and poor land governance have been identified by Gruber (2011) as anthropogenic factors that worsen climate change impacts on UNESCO-designated sites. Whereas UNESCO features a compendium of resources about climate change on designated sites [e.g., https://www.unesco.org/en/climate-change/unesco-sites-climate-change-observatory], Cave (2022) recommends the development of a comprehensive policy on climate change for such sites.

We echo such calls for policy adaptation to climate change as being paramount. Existing policies should be revised to account for the challenges posed by changing climate conditions, with a particular focus on their impacts on UNESCO-designated sites. Integrating disaster risk reduction measures into cultural and environmental conservation policies ensures a holistic approach to resilience. Additionally, policies should strive to incorporate indigenous knowledge alongside scientific insights for enhanced effectiveness.

II.5.4.4. Factors of disaster preparedness in UNESCO sites

The assessment of DRM resources exposes a significant reliance on smartphones, with limited availability of traditional communication tools like pagers/beepers in emergencies. Statista (2023) reports reported a 68% rate for global smartphone penetration in 2022, with notable regional variations as North America and Europe top adoption rates while Sub-Saharan Africa lags. Framing emergency response or preparation actions around smartphone ownership must be within contextual limits, as Scott and Mars (2023), characterize the reality of the developed world as markedly distinct from that of the developing world and suggest approaching mobile phone ownership data with an open-minded perspective. Previously, De Silva (2003) describes the poor state of disaster preparedness in developing countries, pointing to lack of prioritisation of the protection of WHS in funding and capacity building.

Furthermore, the reliance on external agencies for disaster preparation and response equipment underlines the intricate network of stakeholders involved in safeguarding UNESCO sites. On the other hand, such dependence prompts questions about the adequacy of coordination mechanisms and the need for enhanced local capacities. Thus, our findings warrant us to suggest the implementation of continuous and comprehensive monitoring and evaluation mechanisms for disaster preparedness in UNESCO-designated sites as imperative. This proactive approach allows for the adaptation of DRM strategies to changing conditions and emerging challenges. Likewise, specific attention should be directed towards Biosphere Reserves (BRs) due to their expansive territories. We propose the establishment of community-based disaster response teams to enhance local resilience and solve the intricacy of dependency on external resources for preparedness.

The assessment of site preparedness levels unveils challenges in implementing emergency provisions due to the expansive territories of BRs. This finding necessitates a reconsideration of preparedness strategies tailored to the unique geographical features of UNESCO-designated sites. In agreement with our earlier stated hypothesis of a strong positive relationship between perceived resources and disaster preparedness, obtained statistical results as presented in Supplementary Tables S5 and S6 indeed reveal a substantial positive relationship between disaster preparedness and DRM resources.

Furthermore, the combination of disaster awareness and DRM resources emerged as key predictors of disaster preparedness in UNESCO-designated sites. Thus, our earlier hypothesis is accepted to be partially accepted, as it fails to capture risk perception as a determinant for preparedness. Resource allocation and strategic planning to ensure the availability and accessibility of essential DRM tools in addition to increasing disaster awareness at all costs. While the tenets of the basic

PrE model are confirmed by these results, our model only incorporated an additional variable–disaster awareness in predicting disaster preparedness.

II.5.4.5. Limitations of the study

Although this study provides valuable insights into DRM in UNESCO-designated sites, several limitations should be acknowledged. Firstly, the reliance on data from self-reported measures introduces the possibility of response bias, as participants may provide socially desirable responses. Also, responses obtained may not always accurately reflect the actual levels of the concepts measured. Additionally, the study's cross-sectional design limits the ability to include the time dimension in the analyses of variables. Also, the generalizability of the findings may be constrained by the specific characteristics of the UNESCO sites included in the study and the non-probability sampling techniques adopted.

Furthermore, different regions and types of sites may exhibit variations in disaster risk profiles and management practices not fully captured in this research due to the low and disproportionate responses based on these groups. The reliability and depth of this study's findings could be enhanced using more comprehensive local/national studies. Moreover, expanding the sample sizes in future research and attempting probability-based sampling will facilitate more rigorous and robust statistical analyses, increased reliability of outcomes, higher accuracy in findings and generalisability. Despite these limitations, this study contributes to the discourse on disaster preparedness and DRM in UNESCO-designated sites while offering a foundation for future research.

II.5.5. Conclusion

Our comprehensive analysis of DRM within UNESCO-designated sites has illuminated the top hazards they face — wildfires, floods, and droughts. Responding to hazards, therefore, requires tailored and location-specific strategies. While high disaster awareness was recorded among respondents, this is not attributable to disaster experiences within this study. The highest risk perception was noted among African respondents, and amplified vulnerability to hazards in these sites is attributed to climate change and poor environmental management. If disaster preparedness is not improved on these sites, livelihood losses, habitat degradation, and the erosion of the sites' outstanding universal value are looming.

Moreover, the scarcity of pre-listed DRM resources underscores the urgent need for increased availability, as resources correlated with disaster preparedness as per the adopted PrE model. Moreover, the combination of disaster awareness and DRM resources are identified as the two strongest predictors of UNESCO actors' disaster preparedness in this study, extending the PrE, which is limited to perceived adequacy of resources. Given the number of responding countries (i.e., n = 59), stakeholders ought to pay closer attention to tailor-made empowerment of site staff and strengthen community resilience and response capabilities within these sites. Additionally, from expressions of physical and emotional trauma from past disasters the absence of, or inadequacy of trauma support systems in disaster-prone areas is highlighted.

Aside these key improvement areas, we also underscore the need for further research into the intricate interplay between environmental conditions, human activities, and disaster vulnerabilities in UNESCO-designated sites, which remains an unexplored domain. Moreover, future localized studies should explore region-specific risk perceptions and cultural contexts to facilitate more effective and culturally-sensitive resilience efforts. Our recommended initiatives will increase resilience and, in turn, contribute to the sustainability of UNESCO sites, safeguarding natural and cultural heritage for future generations.

Ethical considerations

Before initiating data collection, approval for the questionnaire was obtained from the Department of Geography at Heidelberg University of Education, Germany. Subsequently, a self-review of the objectives and instrument of the study according to stipulated university regulations and research ethics was approved as adequate. Consequently, the study adhered strictly to the principles of good scientific practices outlined in the ethical codes of the American Psychological Association [APA] (2016). Specifically, informed consent, the anonymity of responses, data privacy, and the right to withdraw from the study without any implication were presented to participants in this study. Five participants chose to opt out.

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II.5.6. References

Alam, E., 2016. Earthquake and tsunami knowledge, risk perception and preparedness in the SE Bangladesh. *J Geogr Nat Disasters*, 6(1), 1-7. http://dx.doi.org/10.4172/2167-0587.1000154

American Psychological Association, 2016. *Ethical principles of psychologists and code of conduct*. https://www.apa.org/ethics/code/ethics-code-2017.pdf

Anderson, C. C., Moure, M., Demski, C., & Renaud, F. G., 2023. Risk tolerance as a complementary concept to risk perception of natural hazards: a conceptual review and application. *Risk Anal.*, 1- 18. https://doi.org/10.1111/risa.14161

Becker, J. S., Paton, D., Johnston, D. M., & Ronan, K. R., 2013. Salient beliefs about earthquake hazards and household preparedness. *Risk Anal.,* 33(9), 1710-1727. https://doi.org/10.1111/risa.12014

Below, R., Wirtz, A., & Guha-Sapir, D., 2009. *Disaster category classification and peril terminology for operational purposes*. UCL-Université Catholique de Louvain. http://hdl.handle.net/2078.1/178845

Billman, M., Atoba, K., Thompson, C., & Brody, S., 2023. How about Now? Changes in Risk Perception before and after Hurricane Irma. *Sustainability*, 15(9), 7680. https://doi.org/10.3390/su15097680

Cardona, O.D., M.K. van Aalst, J. Birkmann, M. Fordham, G. McGregor, R. Perez, R.S. Pulwarty, E.L.F. Schipper, & Sinh, B.T., 2012: Determinants of risk: exposure and vulnerability. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, 65-108. https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap2_FINAL-1.pdf

Cave, C., 2022. Climate Change and World Heritage: An Introduction. In *50 Years World Heritage Convention: Shared Responsibility–Conflict & Reconciliation* (pp. 215-225). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-05660-4_17

Chopra, B. K., & Venkatesh, M. D., 2015. Dealing with disasters: Need for awareness and preparedness. *Med J. Armed Forces India*, 71(3), 211. https://doi.org/10.1016/j.mjafi.2015.06.019

Creswell, J. W., 2014. *A concise introduction to mixed methods research*. SAGE publications.

Cui, P., Peng, J., Shi, P., Tang, H., Ouyang, C., Zou, Q., ... & Lei, Y., 2021. Scientific challenges of research on natural hazards and disaster risk. *Geogr. Sustain.*, 2(3), 216-223. https://doi.org/10.1016/j.geosus.2021.09.001

De Silva, N., 2003, November. *Preparedness and response for cultural heritage disasters in developing countries.* International symposium proceedings of cultural heritage disaster preparedness and response, Hyderabad, India (pp.23-27). https://static1.squarespace.com/static/59714798893fc00b04ac9a36/t/598d32cae3df2828b07f29c7/1502425802975/de_silva_Disaster+Preparedness.pdf

Durrant, L. J., Vadher, A. N., & Teller, J., 2023. Disaster risk management and cultural heritage: The perceptions of European world heritage site managers on disaster risk management. *Int J. Disast Risk Re*, 89, 103625. https://doi.org/10.1016/j.ijdrr.2023.103625

Duval, T. S., & Mulilis, J., 1999. A Person-relative-to-Event PrE approach to negative threat appeals and earthquake preparedness: A field study. *J. Appl. Soc. Psychol.*, 29, 495-516. https://doi.org/10.1111/j.1559-1816.1999.tb01398.x

Eze, E., Girma, A., Zenebe, A., Okolo, C. C., Kourouma, J. M., & Negash, E., 2022. Predictors of drought-induced crop yield/losses in two agroecologies of southern Tigray, Northern Ethiopia. *Sci. Rep.*, 12(1), 6284. https://doi.org/10.1038/s41598-022-09862-x

Eze, E., & Siegmund, A., 2023. Flash flood drivers, devastations and directions in UNESCO biosphere reserves: Evidence from a systemic map. *Int J. of UNESCO Biosph Reser*, 7 (1), 23–37. http://dx.doi.org/10.25316/IR-19149.1

Eze, E. & Siegmund, A., 2024. Identifying disaster risk factors and hotspots in Africa from spatiotemporal decadal analyses using INFORM data for risk reduction and sustainable development. *Sustain Dev*, 1 – 22. DOI: 10.1002/sd.2886

Falk, M.T. & Hagsten, E., 2023. Threat Perception and Adaptive Capacity of Natural World Heritage Site Management. Environ Manage, 71(2), 285-303. https://doi.org/10.1007/s00267-022-01780-y

Fricker, R.D., 2008. Sampling methods for web and e-mail surveys. The SAGE handbook of online research methods. London: SAGE Publications Ltd.

Gouda, M., & Yang, Y., 2023. Investigating the impact of a community disaster awareness training on subjective disaster preparedness: the case of Myanar's Ayeyarwaddy region. *Disasters*. https://doi.org/10.1111/disa.12575

Gough, J. D., 1990. *A review of the literature pertaining to 'perceived' risk and 'acceptable' risk and the methods used to estimate them.* Information Paper No. 14, Centre for Resource Management University of Canterbury and Lincoln University

Graham, K., & Spennemann, D. H., 2006. Heritage managers and their Attitudes towards Disaster Management for cultural heritage resources in New South Wales, Australia. *Int. J. Emerg. Manag.*, 3(2-3), 215-237. https://doi.org/10.1504/IJEM.2006.011169

Gruber, S., 2011. The Impact of Climate Change on Cultural Heritage Sites: Environmental Law and Adaptation. *Carbon Clim. Law Rev.*, 5(2), 209–219. http://www.jstor.org/stable/24324033

Gürsoy, A. A., 2019. *An Assessment of disaster risk management in a world heritage site in Turkey: the case of Bergama* (Master's thesis, Middle East Technical University). http://etd.lib.metu.edu.tr/upload/12624916/index.pdf

Ismail-Zadeh, A., 2020. *Placing scientific knowledge, preparedness and public awareness at the core of disaster risk policy.* International Sciences Council, Paris. https://council.science/current/blog/placing-scientific-knowledge-preparedness-and-public-awareness-at-the-core-of-disaster-risk-policy/. Retrieved October 27, 2023.

Ismail-Zadeh, A., 2022. Natural hazards and climate change are not drivers of disasters. *Nat. Hazards* 111, 2147–2154. https://doi.org/10.1007/s11069-021-05100-1

Kang, J. S., Lee, H., & Seo, J. M., 2023. Relationship between nursing students' awareness of disaster, preparedness for disaster, willingness to participate in disaster response, and disaster nursing competency. Disaster *Med. Public Health Prep.,* 17, e220. https://doi.org/10.1017/dmp.2022.198

Landy, J. F., Shigeto, A., Laxman, D. J., & Scheier, L. M., 2022. Typologies of stress appraisal and problem-focused coping: associations with compliance with public health recommendations during the COVID-19 pandemic. *BMC Public Health*, 22(1), 784. https://doi.org/10.1186/s12889-022-13161-5

Lechowska, E., 2018. What determines flood risk perception? A review of factors of flood risk perception and relations between its basic elements. *Nat. Hazards*, 94(3), 1341-1366. https://doi.org/10.1007/s11069-018-3480-z

Lehdonvirta, V., Oksanen, A., Räsänen, P. & Blank, G., 2021. Social media, web, and panel surveys: Using non-probability samples in social and policy research. *Policy & internet*, 13(1), 134-155. https://doi.org/10.1002/poi3.238

Luo L., Wang X., and Guo H., 2022. Contribution of UNESCO designated sites to the achievement of Sustainable Development Goals. *The Innovation* 3(3), 100227. https://doi.org/10.1016/j.xinn.2022.100227

Mañez, M., Carmona, M., Haro, D., & Hanger, S., 2016. Risk perception. https://pure.iiasa.ac.at/id/eprint/13903/1/Chapter3-ENHANCE.pdf

McNutt, M., 2015. Preparing for the next Katrina. *Science*, 3496251, 905-905. https://doi.org/10.1126/science.aad2209

Mokhtari, M., Faridi, P., Masoodi, M., & Mehran Ahmadi, S., 2023. Perspective Chapter: A Global View of Natural Hazards Related Disasters. *IntechOpen.* doi: 10.5772/intechopen.111582.

Mulilis, J.-P., & Duval, T. S., 1997. The PrE model of coping and tornado preparedness: Moderating effects of responsibility. J. *Appl. Soc. Psychol.*, 27, 1750-1766. https://doi.org/10.1111/j.1559-1816.1997.tb01623.x

Mulilis, J.-P., & Duval, T. S., 1995. Negative threat appeals and earthquake preparedness: A Person-Relative-to-Event model of coping with threat. *J. Appl. Soc. Psychol.*, 25, 1319-1339. https://doi.org/10.1111/j.1559-1816.1995.tb02620.x

Nikkanen, M., Malinen, S., & Laurikainen, H., 2023. What drives feelings of responsibility for disaster preparedness? A case of power failures in Finland and New Zealand. *Risk, hazards & crisis in public policy.* 14(3), 179-266.https://doi.org/10.1002/rhc3.12263

Paek, H. J., & Hove, T., 2017. *Risk perceptions and risk characteristics.* In Oxford research encyclopedia of communication. https://doi.org/10.1093/acrefore/9780190228613.013.283

Patel, R. K., Pamidimukkala, A., Kermanshachi, S., & Etminani-Ghasrodashti, R., 2023. Disaster preparedness and awareness among university students: a structural equation analysis. *Int. J. Environ. Res. Public Health*, 20(5), 4447. https://doi.org/10.3390/ijerph20054447

Pavlova, I., Fassoulas, C., Watanabe, M., Canet, C., & Cupa, P., 2019. *UNESCO designated sites—natural and cultural heritage sites as platforms for awareness raising.* Contributing paper to GAR.

Pavlova, I., Makarigakis, A., Depret, T., & Jomelli, V., 2017. Global overview of the geological hazard exposure and disaster risk awareness at world heritage sites. *J. Cult. Herit.*, 28, 151-157. https://doi.org/10.1016/j.culher.2015.11.001

Pavlova, I., Yasukawa, S., Dousseron, A., Jomelli, V., 2021. Landslides at UNESCO-Designated Sites. In: Sassa, K., Mikoš, M., Sassa, S., Bobrowsky, P.T., Takara, K., Dang, K. (eds) *Understanding and Reducing Landslide Disaster Risk.* WLF 2020. ICL Contribution to Landslide Disaster Risk Reduction. Springer, Cham. https://doi.org/10.1007/978-3-030-60196-6_33

Pharaoh, C. D., & Visser, D. J., 2023. Crisis management competencies: A university stakeholder perspective. *J. Contingencies Crisis Manag.*, 1-8, DOI: 10.1111/1468-5973.12508

Porrini, D. & De Masi, F., 2021. Managing climate change risk: The case of the Italian Churches. *Nat Hazards*, 105,.2619-2637. https://doi.org/10.1007/s11069-020-04415-9

Raju, E., Boyd, E., & Otto, F., 2022. Stop blaming the climate for disasters. *Commun. Earth Environ.*, 3(1), 1. https://doi.org/10.1038/s43247-021-00332-2

Rogayan, D.V. & Dollete, L.F., 2020. Disaster awareness and preparedness of barrio community in Zambales, Philippines: Creating a baseline for curricular integration and extension program. *Rev. Int. Geogr. Educ. Online*, 10(2), 92-114. https://doi.org/10.33403/rigeo.634564

Scott, R. E., & Mars, M., 2023. 'Ownership' of mobile phones. J. Int. Soc. Telemed. *eHealth*, 11, e1-1. https://journals.ukzn.ac.za/index.php/JISfTeH/article/download/3145/2128

Shi, P., Ye, T., Wang, Y., Zhou, T., Xu, W., Du, J., ... & Okada, N., 2020. Disaster risk science: A geographical perspective and a research framework. *Int. J. Disaster Risk Sci.*, 11, 426-440. https://doi.org/10.1007/s13753-020-00296-5

Statista, 2023. *Global smartphone penetration rate as share of population from 2016 to 2022*. Retrieved November 11, 2023 from https://www.statista.com/statistics/203734/global-smartphone-penetration-per-capita-since-2005/

Sugio, K. (2015). Large-scale Disasters on World Heritage and Cultural Heritage in Japan: Significant Impacts and Sustainable Management Cases. *Landscape Research*, 40(6), 748–758. https://doi.org/10.1080/01426397.2015.1057806

Thomas, T. N., Leander-Griffith, M., Harp, V., & Cioffi, J. P., 2015. Influences of preparedness knowledge and beliefs on household disaster preparedness. *Morb. Mortal Wkly.*, 64(35), 965-971. https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6435a2.htm

Titko, M., & Ristvej, J., 2020. Assessing importance of disaster preparedness factors for sustainable disaster risk management: The case of the Slovak Republic. *Sustainability*, 12(21), 9121. https://doi.org/10.3390/su12219121

UNESCO, ICOMOS, & IUCN, 2010. *Managing disaster risks for world heritage*. Paris, France. Accessed from https://whc.unesco.org/document/104522 on November 10, 2023.

United Nations International Strategy for Disaster Reduction [UNISDR], 2009. *Terminology*. Geneva: UNISDR. https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction

Valagussa, A., Frattini, P., Crosta, G., Spizzichino, D., Leoni, G., & Margottini, C., 2021. Multi-risk analysis on European cultural and natural UNESCO heritage sites. *Nat. Hazards*, 105, 2659-2676. https://doi.org/10.1007/s11069-020-04417-7

Van Dijk, J. 2005. *The Deepening Divide: Inequality in the Information Society*. London: Sage.

Vyshkvarkova, E., & Sukhonos, O., 2023. Climate Change Impact on the Cultural Heritage Sites in the European Part of Russia over the past 60 Years. *Climate*, 11(3), 50. https://doi.org/10.3390/cli11030050

Weber, M. C., Schulenberg, S. E., & Lair, E. C., 2018. University employees' preparedness for natural hazards and incidents of mass violence: An application of the extended parallel process model. *Int. J. Disaster Risk Reduct*, 31, 1082-1091. https://doi.org/10.1016/j.ijdrr.2018.03.032

Yildiz, A., Dickinson, J., Priego-Hernández, J., & Teeuw, R., 2023. Children's disaster knowledge, risk perceptions, and preparedness: A cross-country comparison in Nepal and Turkey. *Risk Anal.*, 43(4), 747-761. https://doi.org/10.1111/risa.13937

Zuccaro, G., Leone, M. F., & Martucci, C., 2020. Future research and innovation priorities in the field of natural hazards, disaster risk reduction, disaster risk management and climate change adaptation: A shared vision from the ESPREssO project. *Int. J. Disaster Risk Reduct.*, 51, 101783. https://doi.org/10.1016/j.ijdrr.2020.101783.

II.5.7. Supplementary materials (results)

Table II.5–S1: Crosstab results of hazards frequency within various UNESCO-designated site types

Hazards		World Heritage Site (%)	Biosphere Reserve (%)	Others (%)
Ground movement (Earthquake)	NF	68.4	58.9	0.0
	F	31.6	41.1	100.0
Tsunami	NF	68.4	58.9	0.0
	F	31.6	41.1	100.0
Rockfall	NF	59.3	68.6	42.9
	F	11.1	2.0	0.0
Landslide (dry)	NF	58.8	61.1	0.0
	F	41.2	38.9	100.0
Landslide (avalanche of snow, debris, or mudflow)	NF	61.1	67.1	0.0
	F	38.9	32.9	100.0
Volcanic activity	NF	61.1	73.9	0.0
	F	38.9	26.1	100.0
Extreme cold wave	NF	76.5	88.4	66.7
	F	23.5	11.6	33.3
Extreme heatwave	NF	76.5	67.6	66.7
	F	23.5	32.4	33.3
Severe winter conditions	NF	55.6	37.5	33.3
	F	44.4	62.5	66.7
Dense Fog	NF	37.0	30.4	0.0
	F	29.6	38.2	0.0
Extra-tropical storms e.g., cyclones, blizzards	NF	33.3	37.7	33.3
	F	66.7	62.3	66.7
Tropical storms e.g., hurricanes	NF	51.9	39.2	42.9
	F	14.8	28.4	0.0
Convective storms e.g., tornadoes	NF	48.1	49.0	28.6
	F	18.5	19.6	14.3
Flood	NF	58.8	69.6	66.7

	F	41.2	30.4	33.3
Destructive wave actions	NF	47.1	23.6	33.3
	F	52.9	76.4	66.7
Drought	NF	51.9	45.1	14.3
	F	11.1	23.5	28.6
Glacial Lake Outburst	NF	50.0	28.2	33.3
	F	50.0	71.8	66.7
Forest Fire	NF	88.2	98.6	100.0
	F	11.8	1.4	0.0
Land fire of Brush/bush/Pasture	NF	33.3	19.7	0.0
	F	66.7	80.3	100.0
Violent	NF	44.4	19.7	0.0
conflicts/riots/unrest/protest	F	55.6	80.3	100.0
	n	30	12	64

Note: F = Frequent; NF = Not Frequent

Table II.5–S2: Crosstab results of hazards frequency reported by responding UNESCO actors in various continents

Hazards		Africa	Asia	Europe	North America	Oceania	South America
Ground movement (Earthquake)	Not Frequent	70.0	40.0	56.5	50.0	100.0	71.4
	Frequent	30.0	60.0	43.5	50.0		28.6
Tsunami	Not Frequent	70.0	40.0	56.5	50.0	100.0	71.4
	Frequent	30.0	60.0	43.5	50.0		28.6
Rockfall	Not Frequent	66.7	75.0	64.1	55.6	100.0	63.6
	Frequent	0.0	8.3	6.3	0.0	0.0	0.0
Landslide (dry)	Not Frequent	80.0	40.0	46.5	70.0	100.0	71.4
	Frequent	20.0	60.0	53.5	30.0	0.0	28.6
Landslide (avalanche of snow,	Not Frequent	89.5	30.0	55.8	80.0	100.0	57.1
debris, or mudflow)	Frequent	10.5	70.0	44.2	20.0	0.0	42.9
Volcanic activity	Not Frequent	84.2	70.0	64.3	60.0	50.0	71.4
	Frequent	15.8	30.0	35.7	40.0	50.0	28.6
Extreme cold wave	Not Frequent	94.7	60.0	85.4	90.0	100.0	85.7
	Frequent	5.3	40.0	14.6	10.0	0.0	14.3
Extreme heatwave	Not Frequent	78.9	60.0	65.1	80.0	100.0	57.1
	Frequent	21.1	40.0	34.9	20.0	0.0	42.9
Severe winter conditions	Not Frequent	55.0	50.0	34.1	40.0	50.0	28.6
	Frequent	45.0	50.0	65.9	60.0	50.0	71.4
Dense Fog	Not Frequent	46.7	50.0	21.9	27.8	100.0	18.2
	Frequent	16.7	33.3	45.3	27.8	0.0	45.5
Extra-tropical storms e.g.,	Not Frequent	52.6	50.0	26.2	30.0	50.0	42.9
cyclones, blizzards	Frequent	47.4	50.0	73.8	70.0	50.0	57.1

Tropical storms e.g., hurricanes	Not Frequent	36.7	41.7	51.6	38.9	50.0	0.0
	Frequent	26.7	41.7	14.1	16.7	50.0	63.6
Convective storms e.g., tornadoes	Not Frequent	40.0	41.7	57.8	22.2	0.0	63.6
	Frequent	23.3	41.7	9.4	33.3	100.0	0.0
Flood	Not Frequent	73.7	50.0	75.6	50.0	50.0	57.1
	Frequent	26.3	50.0	24.4	50.0	50.0	42.9
Destructive wave actions	Not Frequent	20.0	30.0	34.9	20.0	0.0	28.6
	Frequent	80.0	70.0	65.1	80.0	100.0	71.4
Drought	Not Frequent	40.0	58.3	48.4	27.8	50.0	45.5
	Frequent	23.3	25.0	17.2	27.8	50.0	18.2
Glacial Lake Outburst	Not Frequent	50.0	50.0	27.9	20.0	0.0	14.3
	Frequent	50.0	50.0	72.1	80.0	100.0	85.7
Forest Fire	Not Frequent	100.0	100.0	92.7	100.0	100.0	100.0
	Frequent	0.0	0.0	7.3	0.0	0.0	0.0
Land fire of Brush/bush/Pasture	Not Frequent	15.8	0.0	31.8	30.0	0.0	0.0
	Frequent	84.2	100.0	68.2	70.0	100.0	100.0
Violent conflicts/riots/unrest/protest	Not Frequent	25.0	10.0	30.2	30.0	0.0	0.0
	Frequent	75.0	90.0	69.8	70.0	100.0	100.0
	n	30	12	64	18	2	11

Table II.5–S3: Crosstab results of perceived risk of impacts of future disasters on various UNESCO-designated site types

Item	Responses	World Heritage Site (%)	Biosphere Reserve (%)	Others (%)
Damage to the property's outstanding universal value during emergency response activities.	Unlikely	31.6	35.6	0.0
	Neutral	26.3	24.7	66.7
	Likely	42.1	39.7	33.3
Damage or pressure caused by displaced peoples, particularly regarding camps of displaced peoples, their associated infrastructure and their waste and energy requirements.	Unlikely	47.4	45.2	0.0
	Neutral	15.8	21.9	33.3
	Likely	36.8	32.9	66.7
Encroachment of people into the site	Unlikely	22.2	32.4	0.0
	Neutral	14.8	18.6	0.0
	Likely	33.3	20.6	42.9
Pressure of development and illegal or uncontrolled development.	Unlikely	26.3	41.1	66.7
	Neutral	36.8	19.2	33.3
	Likely	36.8	39.7	0.0
Injury, mortality, or displacement of staff that can reduce the capacity for security, monitoring and enforcement.	Unlikely	26.3	43.8	33.3
	Neutral	31.6	26.0	33.3
	Likely	42.1	30.1	33.3
Loss of livelihood sources linked to the property.	Unlikely	31.6	34.2	66.7
	Neutral	26.3	23.3	33.3
	Likely	42.1	42.5	0.0
Stealing of cultural artefacts on the site	Unlikely	36.8	69.9	66.7
	Neutral	21.1	16.4	0.0
	Likely	42.1	13.7	33.3
Enhanced rate of deterioration of damaged wood or stone.	Unlikely	26.3	41.1	66.7
	Neutral	31.6	20.5	0.0
	Likely	42.1	38.4	33.3
Risk of the loss of authenticity or falsification through reconstruction.	Unlikely	21.1	53.4	66.7
	Neutral	31.6	26.0	0.0
	Likely	47.4	20.5	33.3
Water damage from firefighting.	Unlikely	18.5	35.3	28.6
	Neutral	25.9	14.7	0.0
	Likely	25.9	21.6	14.3
	Unlikely	31.6	42.5	33.3

Unique universal value and integrity are degraded through habitat loss and poaching.	Neutral	10.5	11.0	33.3
	Likely	57.9	46.6	33.3
Pollution from waterborne debris and contaminated watercourses.	Unlikely	14.8	24.5	14.3
	Neutral	18.5	7.8	0.0
	Likely	37.0	39.2	28.6
Damage to site-level office buildings and equipment	Unlikely	18.5	29.4	14.3
	Neutral	11.1	20.6	0.0
	Likely	40.7	21.6	28.6
Hazard-specific risks affect site-level staff	Unlikely	31.6	46.6	33.3
	Neutral	26.3	26.0	0.0
	Likely	42.1	27.4	66.7
Hurricanes and tornadoes can lead to storm surges, which can cause flooding.	Unlikely	47.4	67.1	100.0
	Neutral	15.8	12.3	0.0
	Likely	36.8	20.5	0.0
Earthquakes on my site may cause a tsunami, fire, and landslides	Unlikely	37.0	54.9	0.0
	Neutral	22.2	6.9	0.0
	Likely	11.1	9.8	0.0
	n	27	102	7

Supplementary Table II.5–S4

Mean (SD) and significance test results on responses of this study's variables based on respondents' characteristics and their respective levels.

Respondents' characteristics	Levels	n	Disaster awareness	Hazard frequency	Risk perception	DRM skills and resources+	Vulnerability conditions+	Disaster experiences+	Site's Preparedness+	Hazards preparedness+
Site type	World Heritage Site	27	3.76(0.93)*	2.37(1.13)	3.04(0.97)	4.42(2.97)	2.74(2.35)	4.05(2.59)	5.53(3.2)	1.37(1.39)
	Biosphere Reserve	101	3.55(1.04)	2.62(1.02)	2.58(0.81)	6.62(3.77)	3.89(2.79)	4.12(2.7)	5.25(3.05)	2.68(3.26)
	Global Geopark	1								
	Others[a]	7	2.02(2)	3.51(0.55)	2.69(0.67)	7(2)	3.67(3.06)	3.67(3.79)	5.5(0.71)	0.57(0.98)
	Total	136	3.53(1.09)	2.6(1.04)	2.67(0.85)	6.2(3.67)	3.66(2.73)	4.09(2.68)	5.32(3.03)	2.29(2.96)
Job-status	UNESCO site staff	29	2.99(1.13)	2.61(1.22)	2.76(0.85)	5.26(3.06)	2.78(2.17)	2.79(2.17)	5(3.61)	2.21(2.51)
	UNESCO site manager	35	4(0.55)	2.36(1.03)	2.48(0.84)	6.52(3.77)	3.59(2.61)	4.33(2.86)	4.95(2.78)	2.31(2.93)
	Others	20	3.57(1.16)*	2.73(0.94)	2.74(0.86)	6.48(3.88)	4.13(2.97)	4.64(2.65)*	5.68(2.85)	2.32(3.17)
	Total	136	3.53(1.09)	2.6(1.04)	2.67(0.85)	6.2(3.67)	3.66(2.73)	4.09(2.68)	5.32(3.03)	2.29(2.96)
Site location[b]	Africa	28	3.74(1.32)	2.39(0.91)	3.11(0.63)*	5.33(3.45)	6.61(2.81)***	4.79(3.28)	4.83(3.24)	1.54(2.76)
	The rest of the world	100	3.49(1.04)	2.65(1.07)	2.57(0.87)	6.4(3.71)	2.99(2.23)	3.92(2.51)	5.41(3)	2.49(2.99)

Notes:

[a]'Others' here signifies respondents who are staff members of UNESCO national commissions and neither work in WHS, BRs or GGs

[b]'Site locations' were regrouped into 'Africa' and 'The rest of the world' for analytical convenience. African respondents in this study expressed higher site vulnerability ratings, driving our focus for comparative analyses.

Standard deviation results are presented in brackets next to the mean responses: *Mean (SD)*

+ = variable obtained by summing up individual responses.
***. Mean difference is significant at < 0.01 level.
**. mean difference is significant at the 0.01 level.
*. Mean difference is significant at the 0.05 level.

Supplementary Table II.5– S5

Results of correlation of various variables in the study

		Hazard frequency	Risk perception	DRM skills and resources+	Vulnerability conditions+	Disaster experiences+	Disaster awareness	Site's Preparedness+	Hazards preparedness+
Hazard frequency	Pearson Correlation	--							
	N	96							
Risk perception	Pearson Correlation	.303**	--						
	Sig. (2-tailed)	.003							
	N	95	96						
DRM skills and resources+	Pearson Correlation	.202*	.077	--					
	Sig. (2-tailed)	.049	.456						
	N	95	95	96					
Vulnerability conditions+	Pearson Correlation	.258*	.395**	.190	--				
	Sig. (2-tailed)	.011	<.001	.065					
	N	96	95	95	97				
Disaster experiences+	Pearson Correlation	.317**	.438**	.061	.463**	--			
	Sig. (2-tailed)	.002	<.001	.556	<.001				
	N	95	95	95	95	96			

Disaster awareness	Pearson Correlation	-.051	.039	.213	.006	.152	--		
	Sig. (2-tailed)	.655	.736	.062	.960	.185			
	N	78	78	78	78	78	80		
Site's Preparedness+	Pearson Correlation	-.025	.102	.340**	-.095	.045	.369**	--	
	Sig. (2-tailed)	.830	.374	.002	.408	.696	<.001		
	N	78	78	78	78	78	78	78	
Hazards preparedness+	Pearson Correlation	.368**	.106	.480**	.213*	.204*	.425**	.292**	--
	Sig. (2-tailed)	<.001	.305	<.001	.036	.046	<.001	.009	
	N	96	96	96	97	96	80	78	136

+ = variable obtained by summing up individual responses.

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Supplementary Table II.5–S6

Stepwise regression of predictors of site disaster preparedness

Model		*B*	Std. Error	Beta	R^2 adj.	*F*	*t*
1	(Constant)	0.996	1.290			11.98***	0.77
	Disaster awareness	1.193	0.345	0.369	0.13		3.46**
2	(Constant)	0.157	1.284				0.12
	Disaster awareness	1.005	0.340	0.311	0.19	9.84***	2.95**
	DRM resources	0.237	0.091	0.274			2.61*

n =78

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Name, first name	Eze, Emmanuel	Siegmund, Alexander	
Methodology	✓		
Software			
Validation			
Formal analysis	✓		
Investigation	✓		
Resources	✓	✓	
Data Curation	✓		
Writing-Original Draft	✓		
Writing-Review&Editing	✓	✓	
Visualization	✓		
Supervision		✓	
Project administration	✓	✓	
Funding acquisition	✓		

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6

"Strength does not come from physical capacity. It comes from an indomitable will." ~
Mohandas Karamchand Gandhi

II.6. Enhancing protection motivation for disaster preparedness among actors at UNESCO-designated heritage sites in Africa

Abstract

Heritage sites face escalating threats from natural and human-induced hazards, posing risks to centuries of cultural heritage and environmental diversity. Despite this pressing challenge, there is a notable scarcity of qualitative studies linking protection motivation and disaster preparedness in UNESCO-designated sites. Guided by the Protection Motivation Theory (PMT) this study fills this critical gap by examining these aspects within UNESCO-designated sites in Africa. By adopting a directed qualitative content analysis approach, key informant interviews of 21 actors, covering 10 countries provided pertinent data for this study. While threat appraisal was strong, coping appraisal was weak, with partial disaster preparedness among UNESCO actors. Notably, the absence of fear as a predominant motivating factor for protection and disaster preparedness was compensated by other factors namely: a strong sense of heritage stewardship, and sustainability/resilience commitment. These findings extend the PMT framework and advocate for future research integrating elements of place attachment theory. By leveraging these insights, stakeholders can collaboratively enhance preservation efforts, ensuring the long-term sustainability of Africa's cultural and natural heritage.

Keywords: Disaster preparedness; heritage protection; natural hazards; protection motivation theory; UNESCO-designated sites

Highlights

- Fear is not a motivation for protection and disaster preparedness
- The PMT is extended by heritage stewardship and sustainability commitment
- High risk perception and confidence in disaster risk reduction measures
- Inadequate human, material, and financial resources allocated to heritage conservation
- Low levels of self-efficacy coupled with partial disaster preparedness

II.6.1. Introduction

Heritage sites are now faced with more frequent and intense natural hazards, which pose a formidable challenge to their continued existence. Due to social factors such as high vulnerability and lack of coping capacity, natural hazards lead to disasters, which threaten these invaluable treasures, with the potential of erasing millennia of rich human history and environmental splendour in catastrophic events. The commitment to safeguarding our collective heritage amidst these looming threats is reflected in the constant recognition of some of these tapestries of cultural and natural wonders by the United Nations Educational Scientific and Cultural Organization (UNESCO).

Based on their uniqueness, these sites have been designated as either Global Geoparks (GGs), Biosphere Reserves (BRs) or World Heritage Sites (WHS). Pavlova et al. (2019) describe GGs and BRs to be areas of unique geological and biodiversity conservation landscapes with opportunities for education and research, and WHS designated for their significant cultural or historical outstanding universal value. Our study is thus delimited to these UNESCO-designated sites, especially in Africa renown for high vulnerability to disasters.

Therefore, the imperative for robust disaster preparedness measures within these UNESCO-designated sites becomes increasingly evident. The ability of site managers and their staff to anticipate, mitigate, and respond to hazards holds profound implications for the preservation of these sites and the communities that rely on them for sustenance, livelihoods, and cultural identity. Yet, despite recognising this pressing need, our understanding of the factors influencing protection motivation and disaster preparedness in UNESCO-designated sites remains fragmented, with persisting knowledge gaps regarding the motivations, perceptions, and efficacy of preparedness efforts.

For example, Pavlova et al. (2017) conducted a global disaster risk awareness of WHS managers while Graham and Spennemann (2006) earlier focused on Australian heritage managers' attitudes towards disaster planning for cultural heritage resources. Recently, Durrant et al (2023) examined the perception of

European WHS managers on disaster risk management. Moreover, previous works by the authors of the current paper have assessed competencies, competency gaps and factors of disaster preparedness through a global survey, with managers of UNESCO-designated sites in Africa rating higher in vulnerability, risk perception, competency gaps, and indicating lower disaster preparedness rates (Eze & Siegmund 2024a, b, c).

Thus, this paper aims to build on our previous studies and address a critical gap by assessing the protection motivation and disaster preparedness within UNESCO-designated sites in Africa. We focus on African sites due to already established high vulnerability levels to disasters described by Bündnis Entwicklung Hilft & Institute for International Law of Peace and Armed Conflict (IFHV) (2023) and Eze & Siegmund (2024). Central to our study is the integration of the Protection Motivation Theory (PMT) of Rogers (1975). According to the basic PMT (Figure II.6–1), a person's protection motivation, which manifests as the behavioral intention to initiate or sustain protective actions, hinges on their threat appraisal and coping appraisal.

While threat appraisal comprises perceived vulnerability (i.e., the likelihood of encountering potential threats),perceived severity (i.e., the degree of the consequences of the threat) and fear (i.e., an emotional response to hazard occurrence); coping appraisal includes three elements: self-efficacy (i.e., expressed confidence in one's ability to handle a potential threat), response efficacy (i.e., belief in the effectiveness of recommended protective actions to mitigate a threat), and response costs (perception of the resources required to implement protective measures).

Ultimately, as per PMT, individuals are motivated to adopt protective behaviors if they believe the benefits outweigh the risks, and both their perceived self-efficacy and response efficacy must outweigh the costs associated with adaptive responses. Originally a health promotion model, the PMT is being increasingly adopted in evaluating risk reduction and disaster preparedness research. The basic assumption of the PMT is that exposure to risk-related information can stimulate motivation by enabling individuals to assess the severity of a risk, their vulnerability to it, and their capacity to mitigate the risk (Tang & Feng, 2018; Faryabi et al., 2023).

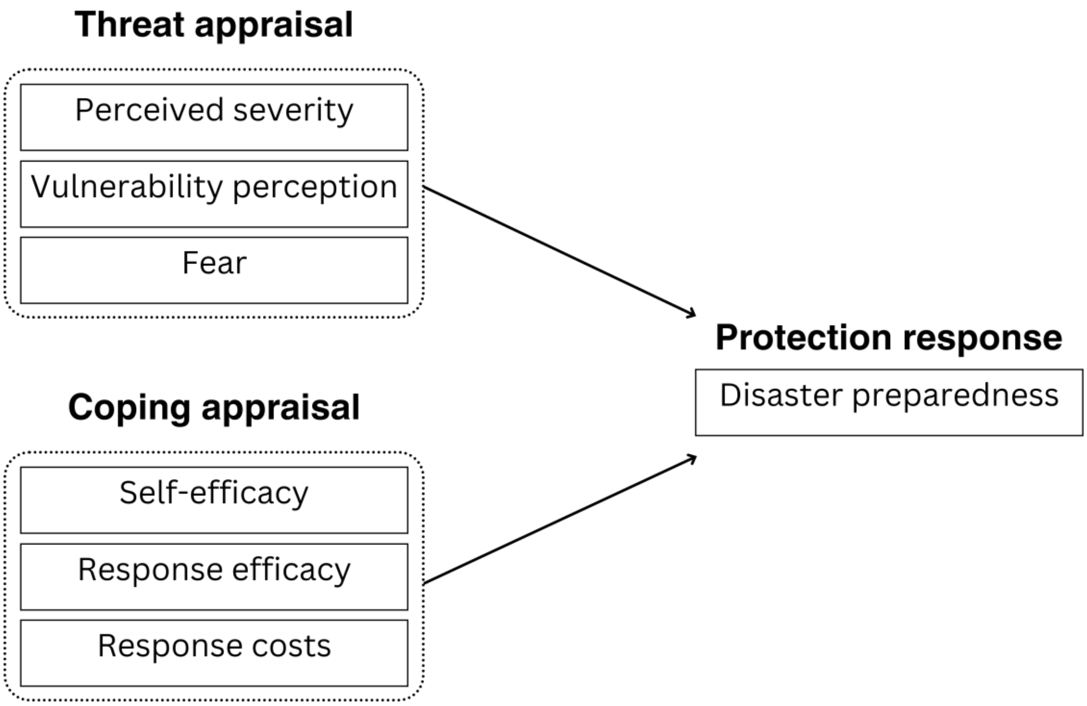


Figure II.6–1: Basic protection motivation theory framing this study

We, therefore, apply the PMT as a guiding framework in this qualitative study to determine the protection motivation and disaster preparedness of UNESCO actors within African UNESCO-designated sites. The aim is to shed light on supporting and non-supporting factors of protection motivation of UNESCO actors. Ultimately, we seek to provide actionable insights that can inform evidence-based interventions and policies aimed at enhancing disaster preparedness in UNESCO-designated sites. The conceptual extension of the PMT is envisaged by our study, which also contributes to the emerging scholarly discourse on disaster risk management and heritage conservation in the face of escalating environmental challenges threatening our collective heritage.

II.6.2. Methods

II.6.2.1. Study Design

In this study, a directed qualitative content analysis (DQCA) approach was employed. DQCA, as outlined by Hsieh and Shannon (2005), follows a structured deductive approach to develop codes, categories, and themes from qualitative data, aiming to validate or conceptually extend a theory through supporting and non-supporting evidence. Given the utilization of the PMT as our theoretical framework, the DQCA method was well-suited, incorporating both deductive and inductive techniques to align with the PMT framework (deductive) while allowing for narratives from respondents to yield rich insights (inductive). This deductive-inductive approach is supported by Elo and Kyngäs (2008), who suggest that a deductive content analysis is beneficial for testing prior theories in new contexts or comparing categories across varying time frames while an inductive approach is suitable for addressing novel phenomena or fragmented knowledge.

II.6.2.2. Sample

Participants of this study are referred to as UNESCO site actors, comprising individuals from various backgrounds and roles within UNESCO-designated sites, national commissions and regional offices in Africa, and relevant sections of the UNESCO Headquarters in Paris, France. Respondents are engaged in the management and oversight of UNESCO-designated sites with significant responsibilities of site management and conservation, environmental education, policymaking, and research initiatives within these areas.

The work of Durrant et al. (2023) describes these stakeholders as key in the implementation of the Sendai Framework for Disaster Risk Reduction, particularly within the context of heritage, as their experiences uniquely position them to understand these sites better. Therefore, recognising the distinct insights and extensive experiences of our respondents, we anticipated robust perspectives on their protection motivation and disaster preparedness within these sites (Table II.6–1).

Table II.6–1: Information on participants

Code[1,2]	Site Type[3]	Gender	Educational qualification	Years of experience	Position of respondent
001H	WHS	Male	Master's	20	Site manager
002H	BR	Male	Master's	6	Officer
003U	UNESCO	Male	Master's	5	Project manager
004U	NATCOMM	male	Doctorate	5	Head of unit
005U	UNESCO	male	Master's	3	Site manager
006H	BR	Female	Bachelor's	9	Project manager
007H	BR	Male	Master's	10	Forest manager
008H	BR	Male			Forest engineer
009H	BR	Male	Bachelor's	10	Site manager
010H	BR	Male	Doctorate		Staff
011H	BR	Male	Doctorate	10	Head of unit
012H	WHS	Male	Diploma	35	Site manager
013U	UNESCO	Male	Bachelor's		Head of unit
014U	UNESCO	Male	Doctorate	14	Head of unit
015H	BR	Male	Master's	23	Site manager
016U	NATCOMM	Female	Master's	5	Staff

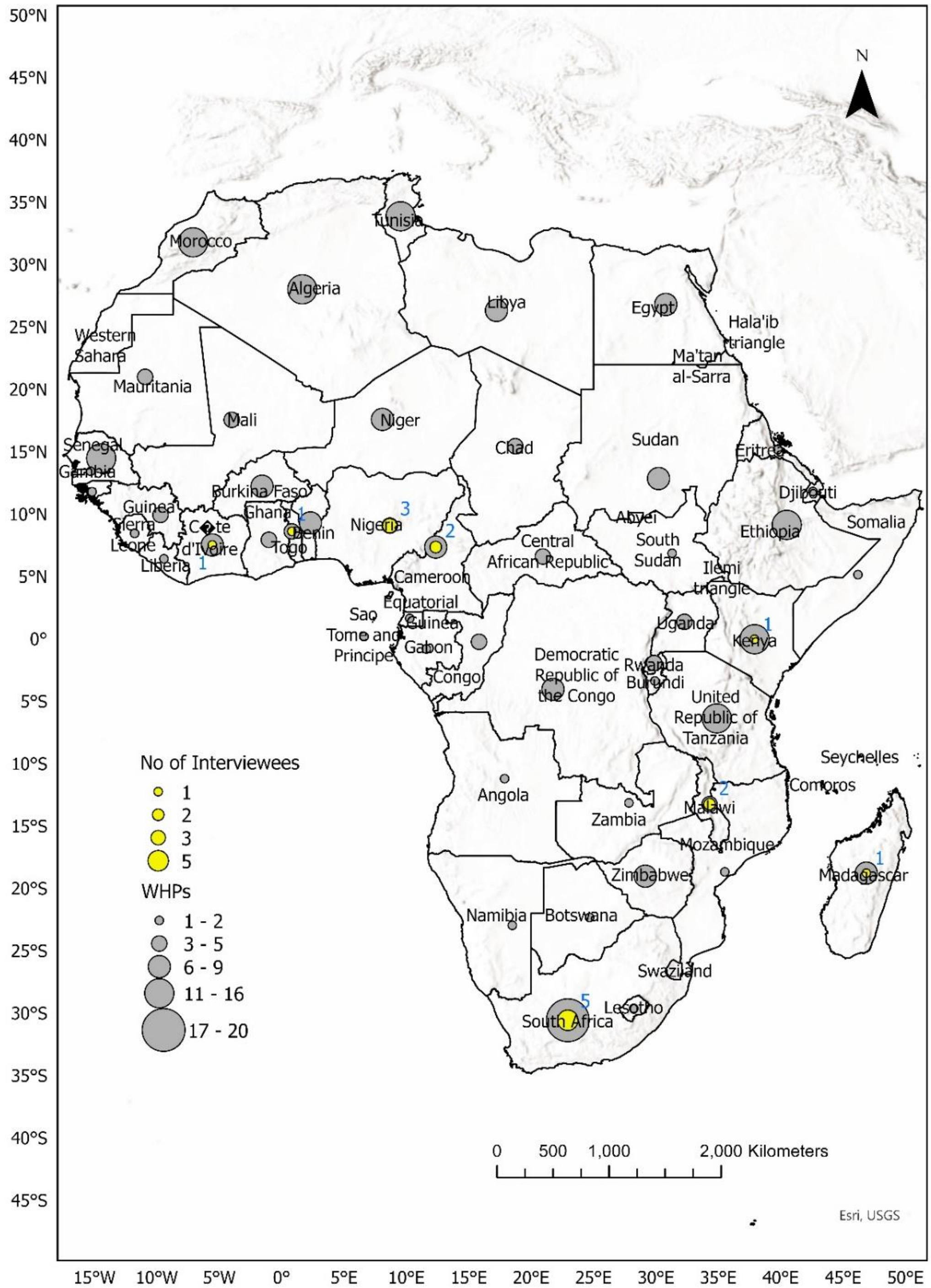
017U	UNESCO	Male	Doctorate	28	Head of unit
018H	BR	Male	Master's	2	Site manager
019H	BR	Male	Doctorate	8	Site manager
020U	NATCOMM	Male	Doctorate		Focal person
021U	NATCOMM	Male	Bachelor's	18	National coordinator

Notes:
[1] Each respondent is designated a unique code derived from a hierarchical numbering system based on the sequence of their interviews from 001 to 021. The alphabetic code, "U" or "H" is assigned to indicate whether the participant is affiliated with UNESCO headquarters, regional or national offices (denoted as "U"), or with a heritage site management or staff role (denoted as "H").
[2] Countries of respondents (Figure II.6–2): Cameroun ($n = 2$), Comoros ($n = 1$), Cote D' Ivoire ($n = 1$), France ($n = 4$), Kenya ($n = 1$), Madagascar ($n = 1$), Malawi ($n = 2$), Nigeria ($n = 3$), South Africa ($n = 5$), and Togo ($n = 1$).
[3] BR = UNESCO biosphere reserve; NATCOMM = UNESCO National Commission; UNESCO = UNESCO Headquarters or Regional Office; WHS = UNESCO world heritage site; UNESCO

We employed a combined sampling approach, utilizing harvested email lists (Fricker, 2008) and river sampling (Lehdonvirta et al., 2021), both falling under the convenience non-probability sampling method. The harvested email lists consisted of email addresses belonging to managers of UNESCO-designated heritage sites in Africa, as well as members of the Heritage Unit and Man and Biosphere Unit at UNESCO Headquarters in Paris, France, sourced from various online platforms. In our invitation emails, we embedded links for recipients to express interest in participating in our study, aligning with river sampling, which involves inviting respondents from a specific population to take part in a survey through links placed on websites or emails.

Therefore, we extended study invitations to 264 professional email addresses of UNESCO site actors, with timely weekly reminders sent from October 9 to November 27, 2023, to enhance response rates. The significant limitation of both sampling methods in this study is the non-generalizability of our findings beyond active respondents and the sites they directly oversee or manage, resulting in coverage bias (Lehdonvirta et al., 2021). This bias is exacerbated by disparities in internet access, usage patterns, and visit frequencies (Van Dijk, 2005).

Figure II.6–2: Map of Africa showing the countries of respondents in this study and the number of



UNESCO-designated World Heritage Properties

Note: The map does not include the four respondents from various strategic units and positions at the UNESCO Headquarters, Paris, France

Moreover, in our study, the eventual number of participants was determined based on the principle of data saturation achieved after conducting in-depth interviews with 21 UNESCO actors (Figure II.6–2). Saturation, a criterion for discontinuing data collection or analysis in qualitative research (Saunders et al., 2018), was observed in two forms: data saturation and thematic saturation. No new themes emerged, and additional interviews did not yield further insight into the topic.

Specifically, the final two respondents did not contribute new data or themes, leading to the conclusion of data collection. Importantly, respondents hailed from nine African countries, covering over ten sites across Central, Eastern, Western, and Southern Africa. While our findings may not represent all African UNESCO-designated sites, the insights provided by respondents, including strategic heads of units within UNESCO national, regional and global headquarters, offer valuable contributions to our study.

II.6.2.3. Data Collection

The lead researcher (EE), possessing extensive expertise in climate change and disaster risk management, facilitated all interviews using Microsoft Teams, a video conferencing platform. Before each interview, the research objectives and interview procedures were explained, and verbal consent for recording was secured. Participants were allowed to seek clarification and were assured of the confidentiality and anonymity of their responses, thereby fostering an environment conducive to open discussion. Employing a semi-structured interview guide shown in Table 2, the interviews were conducted flexibly to ensure seamless progression while allowing participants to express themselves freely and providing in-depth exploration of the research question.

The total duration of interviews is about 1,504 min, ranging between 20 and 75 minper interview, and with an average duration of 52 min. After each interview, comprehensive field notes were recorded to capture noteworthy insights. Audio recordings of all interviews were transcribed verbatim, and transcripts were anonymized by removing identifiable information.

While we acknowledge the limitation of this study as not integrating various data sources, such as focus groups or quantitative survey data, our findings could serve as a foundation for future research to comprehensively explore protection motivation and disaster preparedness in heritage properties. By incorporating additional data sources, future studies may extend the scope of our conclusions, providing a more comprehensive understanding of the subject matter.

Table II.6–2: Interview guide

Items
Study information (objectives and procedures) and consent to participate.
Personal information: the highest level of education, roles and responsibilities and preferred sources of Information on climate change and disasters?
Hazards/Disaster frequency (natural and human hazards in sites).
Any striking examples of impacts of hazards/disasters on sites?
Why are the site and its occupants vulnerable to frequently occurring hazards?
Perception of climate change-driven disasters on site.
Disaster risk assessment: methods and frequency.
Personal motivation for disaster risk reduction/management.
Disaster preparedness of sites: resources for prevention and emergency provisions available.
How to improve disaster preparedness?
Level of engagement with local communities.
Any successful disaster risk reduction initiatives?
Main challenges for disaster risk management/reduction on site.
Capacity level of staff in disaster risk management/reduction.
What are must-have competencies/skills for disaster risk management/reduction on sites?
What training opportunities are available?
What funding opportunities are available?
Comments on staff strength in sites.
Are there early warning systems in place? If yes, are they effective in triggering actions?
Other comments on the topic or related?

II.6.2.4. Ethical Considerations

The study adhered to the guidelines outlined by the American Psychological Association [APA] (2016) and the European Data Protection Law. Furthermore, following the research ethics approval of the Heidelberg University of Education, Germany and regulations governing doctoral research, the study was meticulously planned and conducted by the lead author.

II.6.2.5. Analysis

The lead author performed both transcript pseudonymization and computer-based analysis using MAXQDA 2022 (VERBI Software, 2021). MAXQDA, a comprehensive qualitative data analysis tool was used in transcribing and analyzing audio and video recordings and performing content analyses on the derived transcripts in this study. The analyses involved a deductive–inductive approach.

Therefore, guided by the components of the Protection Motivation Theory (PMT), a preliminary category system was developed. Subsequently, relevant excerpts from the interview transcripts were assigned to these predefined categories during the coding process, with new categories generated during the coding.

II.6.2.6. Reflexivity and Trustworthiness

Reflexivity, according to Olmos-Vega et al. (2023), encompasses various facets of the research process, including personal, interpersonal, methodological, and contextual factors, for acknowledging and addressing the potential influence of the researcher's subjectivity and perspective on the study outcomes. Our research team consisted of members with diverse backgrounds in geography, education, climate change, and disaster risk management, bringing extensive experience in qualitative research methodologies, particularly structured and semi-structured interviews.

The lead author (EE), a male doctoral student with a bachelor's and two master's degrees in geography education, environmental education, and climate science, conducted, processed, and analyzed the interviews. Alongside university-level teaching experience, which honed skills in high-order questioning and interview techniques, he possesses prior expertise in qualitative content analysis and mixed-method research. No pre-existing relationships existed with the participants; however, the lead author made a brief introduction of himself, the study's objectives and potential significance before obtaining consent to proceed with and record the interview session.

The interpretation of findings relied on theoretical assumptions of the PMT and participants' responses, fostering a deductive-inductive analytical approach. The transcription of interviews was also performed by the lead author (EE), ensuring data reliability. Lastly, to enhance the trustworthiness of our findings, we follow the principles and recommendations of Rockmanna and Vough (2023) and have incorporated various types of interview quotes in the presented results. However, to maintain anonymity while presenting respondents' quotes and findings, pseudonyms corresponding to their assigned codes are used throughout this article.

II.6.3. Findings

Our study findings are structured under relevant headings aligned with the key elements of the PMT. To ensure precise referencing of quoted text supporting our findings, we use the unique code of respondents described in Table 1 and the position (i.e., Pos) of the quoted text within the interview transcript as processed in MAXQDA.

II.6.3.1. Threat appraisal

Respondents highlight the multifaceted nature of threats from various environmental stressors and hazards faced by UNESCO-designated sites in Africa. Both nature-induced disasters like droughts, floods, and cyclones, as well as human-induced hazards such as wildfires, erosion, and pollution, were severally identified. Furthermore, while some respondents acknowledge the impact of climate change on exacerbating these hazards, others attribute them to localised human activities such as deforestation, mining, and pollution.

Aside from governance issues, such as ineffective law enforcement and resource mismanagement, lack of infrastructure, inadequate preparedness, and limited resources are regarded as key drivers of vulnerability within the host communities of UNESCO-designated heritage sites. Communities are reported to experience disruptions to livelihoods, loss of biodiversity, and substantial threats to heritage sites due to the combination of hazardous events and their vulnerability. Subsequently, the components of threat appraisal are summarised and substantiated with direct quotations from responding actors of UNESCO-designated heritage sites in Africa.

II.6.3.1.1. Perceived severity

All respondents presented a strong perception of the possible consequences of hazardous events. To represent the perceived severity component of the PMT within this study, we present the frequency of hazard occurrences in all responses within the interview transcripts in addition to analysed coded excerpts of their consequences. In the order of magnitude, frequently occurring hazards in UNESCO-designated sites include wildfires, floods, drought, cyclones, landslides, violent conflicts, locust invasion and windstorms (Figure II.6–3). Moreover, gender and age are identified as key vulnerability factors in disasters, with women, girls, the youth, and the elderly being disproportionately affected.

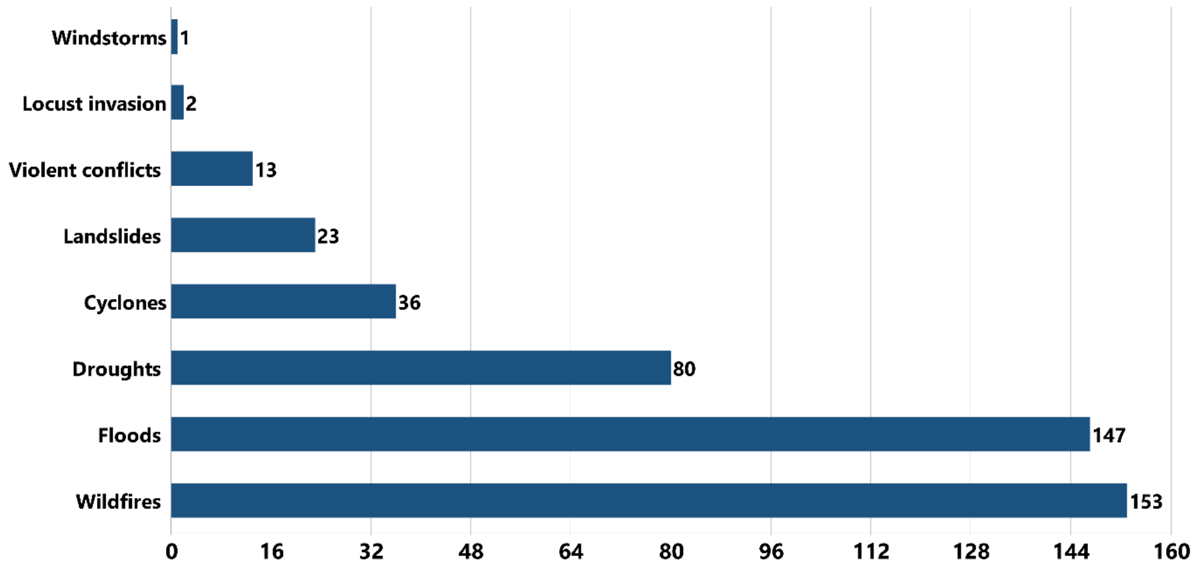


Figure II.6–3. Coded segments of frequent natural hazards in UNESCO-designated sites

Generally, a UNESCO chief of unit asserts that "there was a perceived, very tangible increase in the number of hazards and in those hazards resulting in disasters." (017U, Pos. 29). However, the severity and impacts of these hazards vary across responses. For example, recent cyclones and floods in Malawi, an East African country displaced long-term occupants within a biosphere reserve as "the lake swelled up and a larger part of some spaces where people had been occupying for the past 50 years, been displaced by water." (002H, Pos. 26).

Conversely, a southern African respondent states that

> "Frequently occurring fire is probably the most frequent, followed by drought, followed by wide-scale erosion, you know, loss of topsoil. It's one of those sort of quiet risks that then suddenly the farmers wake up and the crops are gone and the crops are dead and then the people are hungry and then there's all sorts of problems. Just as much as when a fire goes through or when there's a flood. But, you know, a degraded landscape starts with soil loss". (019H, Pos. 59-60)

A UNESCO staff from eastern Africa specifically designated the top three hazards as drought, floods and cyclone winds with an interesting highlight of consecutive flood-drought occurrences. They indicate that

> "...sometimes in a year we have drought and sometimes we have floods. But they do not occur at the same time. But they may occur one after the other. Like in 2013, 2014, we had floods. But in 2015, towards the end, we had drought. So, they more or less like occur sometimes one after another.

They do not occur at exactly the same time, but afterwards." (016U, Pos. 45-47).

N Notably, whereas both heritage site managers and UNESCO staff (i.e., those affiliated with UNESCO headquarters, regional or national offices) recognise similar hazards, vulnerability factors and impacts, differences in attribution of hazards and expressed disaster preparedness levels are observed. For example, while site managers tend to attribute environmental hazards more explicitly to climate change, emphasizing its role as a major disaster driver, responding UNESCO staff discuss a broader range of factors including both climate change and local human activities in their responses as shown in reproduced responses below.

> "So we always think that climate change has been the biggest driver, because like the dryouts, we think it has been exacerbated by climate change and variability. Yeah. Even the cyclone Fred last year, we think is also partly, or the bigger part because of climate change. We think so, of course we haven't collected enough data to verify, but climate change is really a major driver. (002H, Pos. 79-80)"

> "You know, we are told that as a result of climate change, we are also going to have higher incidences, higher frequency of fires. Too much rainfall will translate to what? Increased frequency of landslides. Isn't it? And of course, landslides may also happen, one, because you've cleared the surface. So, you've cleared our ecosystems, thus exposing the landscape and the surface to vulnerability, to any shaking, to any runoff that then ends up carrying away huge swathes of land together with the vegetation. (004U, Pos. 156-157)"

II.6.3.1.2. Vulnerability perception

Responses on the impact of disasters on the outstanding universal values (OUV) of UNESCO-designated sites present a complex issue with divergent perspectives. Some stakeholders argue that disasters have no direct negative impact on the OUV, citing examples such as cyclones that primarily impact livelihoods rather than the integrity of the site itself. For instance, in the aftermath of cyclones, increased water volumes have been beneficial for managing fisheries, contributing positively to certain sectors within the site (002H). Similarly, droughts are perceived as having minimal direct impact on the OUV but are acknowledged for their effects on local livelihoods and landowners within the site (012H, Pos. 64-65).

> "As of now, no, not yet, because the main things that we are treasuring are first the migratory birds, and also fish. So like for my sector, the fisheries department, this year we are, apart from the devastation of the cyclone, we are so happy because we have huge volumes of water. And that has been good for us to manage the fish. And we see some of those fisheries are happier because they have more fish landing now." (002H, Pos. 29-30)

Contrastingly, some responses contend that disasters significantly affect the OUV, particularly citing examples such as droughts and floods that pose substantial threats to biodiversity and ecological processes. Droughts, for instance, are highlighted as a major concern due to their adverse effects on bird and fish populations, leading to significant ecological imbalances within biosphere reserves. Similarly, floods resulting from factors like dam releases (e.g., from Nangbeto dam in Togo) are identified as catastrophic events that directly impact habitats and human settlements within the site, disrupting educational and agricultural activities for a while.

Moreover, the perceived likelihood of adverse disaster impacts on the OUV of UNESCO-designated sites is reflected in human-induced factors identified as exacerbators of disaster vulnerability within these sites. Illegal activities stemming from poverty and resource exploitation pose additional risks to the integrity of the site, affecting attributes such as biodiversity and geological formations. Pollution from various sources, including industrial activities and mining, further degrades the ecological health of water bodies within the site, leading to mass fish deaths and habitat degradation.

> "...poverty or extreme poverty, the lack of means of subsistence in the regions..., encourages certain people to carry out illegal activities that can have consequences on the attributes of exceptional universal values, such as the integrity of the site or the presence of animal species...From a socio-economic point of view, the poverty of populations in the peripheral zone is an aggravating factor of potential risks of illegal activities." (009H, Pos. 91-92)

Furthermore, the combination of hazards, such as invasive alien plants and poor land management practices, worsens disaster impact on biodiversity and ecosystem resilience. Invasive plants, for example, increase the risk of wildfires, which can devastate large areas of forests and compromise the stability of ecosystems for decades. Similarly, fires have been shown to destroy critical habitats and vegetation, leading to both habitat loss and compromising the resilience and ability of such ecosystems to recover from subsequent disasters.

"...the invasive plants grow much quicker. So, they get bigger, they get higher, they have higher fuel loads than the natural vegetation. And they are very flammable...We're talking 150,000 hectares of forests and invasives and towns and people dying and the thousand houses being burnt and all of that...And it was actually, there were three areas, so it was probably closer to 200,000 hectares in total that got burned in a matter of three weeks. And that was a result of a combination of very dry drought kind of conditions, invasive aliens that were ready to burn, and yeah, just bad agricultural practices, people not keeping their fire breaks properly and so on. (019H, Pos. 65-69)

"The same thing I believe happens in Mount Kenya where we have frequent fires. It ends up actually compromising the resilience and stability of these ecosystems...And it destabilizes the ecosystem to an extent that it becomes very difficult to take back the ecosystem back to where it was before this happens. And of course, if this has to happen, then it means it has to take a long period of time...it may be 50 years, it can even be 100 years. And you can imagine a destruction happening in a month or a week or days and you require hundreds or tens of years for that system to recover (004U, Pos. 64-78)

II.6.3.1.3. Fear

Although fear is not explicitly mentioned, the interviews reveal a range of emotions, including stress, desperation, and displeasure, which are indicative of underlying fear appeal within the context of PMT. For example, community members identified temperature, windstorms, and drought as stressors with significant threats to the environment (001H, Pos. 145-146). Similarly, the drying up of lakes due to drought leads to desperation among the community members, forcing some individuals to resort to drastic measures like tree cutting for charcoal production and sustenance (002H, Pos. 39-40). Additionally, concerns about overflow at a site triggered displeasure among site managers (008H, Pos. 38).

II.6.3.2. Coping appraisal

Respondents expressed a lack of confidence in the efficacy of current coping mechanisms and resource allocation strategies when faced with recurring disaster-related threats within UNESCO-designated sites. Issues such as competing priorities for government funding, limited technical expertise, and governance gaps were identified as limiting factors, posing significant challenges to the development of effective preparedness and response efforts. Consequently, these challenges contribute to heightened vulnerabilities within the sites.

Despite these obstacles, several notable efforts were identified as favourable for enhancing coping mechanisms. These include empowerment programs aimed at engaging local communities and providing alternative sources of income, the establishment of conservation clubs in schools to raise awareness among the youth, conducting comprehensive risk assessments to identify vulnerabilities, and the implementation of early warning systems to improve disaster preparedness. These capacity-building initiatives were recognized as essential steps towards increasing resilience and response efficacy within the sites. However, there remains a consensus among respondents that additional efforts are needed to effectively address current environmental threats and enhance coping mechanisms within UNESCO-designated sites. Described below are the findings from the coping appraisal components, drawn from the participants' responses in this study and supported by selected direct quotations.

II.6.3.2.1. Response efficacy

Respondents conveyed their perception of the effectiveness of several actions to mitigate disasters on their sites. Three key aspects of vulnerability and risk assessments, projects and programmes, and early warning messages were recurrent. These elements play a crucial role in showcasing proactive measures in response to hazard occurrences in UNESCO-designated heritage sites.

Respondents describe various approaches to monitoring and reporting on conservation efforts in some of the sites. Regular reconnaissance in these sites proactively assesses the effectiveness of conservation strategies and provides timely information on potential risks to enhance site-specific responses. Sometimes, assessments were limited to frequently occurring hazards within the community.

> “Every year, at the end of every rainy season, we conduct a reconnaissance survey. We report to the National Commission every quarter if there is an uncertain observation. So, that is how we monitor and give updates on the conservation of the site.” (001H, Pos. 135-136)

> “...the assessment that was done was done by the Fire Protection Association. And we basically focused on the wildfire threat. And we indicated to the provincial structures, this is the places where we need to make fire breaks to protect this community, to protect security and so forth.” (015H, Pos. 100)

> “So, what we have done is that we have done the vulnerability assessment throughout the country, but focusing particularly at the district level...So out of those assessments, there are specific activities that have been

> identified that will be least or that will be affected and those that will be least affected. So, it's a site-specific response based on the things that are happening within that particular area, but also depending on the economic industries...within that particular area. (021U, Pos. 75-76)

Various empowerment programs target farmers, hunters, and school children, aiming to raise awareness about environmental conservation and climate change adaptation through alternative livelihoods, organic farming, and sustainable resource management. Specific projects like the 'Dinkwayane Water Smart Project' and the 'Blue Deal Project' aim to enhance community resilience through improved water quality, wastewater treatment, and disaster preparedness measures. In addition, UNESCO is involved in projects such as 'Be Resilient' to improve climate risk monitoring and early warning for adaptive planning and to conduct capacity building on the Climate Risk Informed Decision Analysis (CRIDA) through citizen science. Moreover, other noteworthy initiatives include prescribed burning and a focus on promoting good farming practices and tree planting for improved infiltration and minimal soil erosion, and advocating for the construction of stronger, disaster-resilient houses.

> "...the biggest parts we are trying to do is like for the farming communities, we are encouraging them to follow proper husbandry practices, good farming practices, so that we minimize soil erosion. And also we are trying to request to ask most of the communities upland to plant more trees, to encourage infiltration and reduce soil erosion...last year, we launched what we called from the disaster side, we called Build Better. So we are encouraging the communities to consider building stronger houses, that which those that can be able to withstand some of those disasters." (002H, Pos. 82-83)

> "...in the area of environmental education and awareness, we do that regularly...what we try to get communities to do, women and even the leaders, in terms of maybe the teens, are carried along... we extend this environmental education and awareness to secondary schools and primary schools. We have conservation clubs in most of these communities...Another thing, especially in the area of wildfires,...at the end of the rainy season, we intentionally apply fire to the grassland area that is very close to the buffer area...to avoid wildfire incidents. (011H, Pos. 135-140)

Respondents highlight the implementation and effectiveness of various early warning systems in disaster preparedness and response. These systems include river-level alarms, WhatsApp groups, collaboration with government meteorological agencies, and international partnerships. While some methods, such as river-level alarms and WhatsApp groups, show effectiveness in alerting communities to impending disasters, challenges like communication accessibility and trust issues persist.

> "Yes, we have some of them, we have trained the communities that we use, even local or indigenous knowledge, when disease happens, and then you know something bad is coming. Some rivers, we have installed some alarms, so when the water levels in certain rivers have reached a certain height, then the communities in the lower side, the alarm will blow off, and then people know there's something that is going to happen, so they start either evacuating their homes and all that. But again, we have loudspeakers, so sometimes community members that belong to the committee, the civil protection committee, they will still be able to move around communities with the loudspeakers, to tell them about anything that would happen…We also use local or community radio stations, send information, and then it's broadcasted, …It has worked to a certain extent, yes. But sometimes like the radio, people are not listening to the radio, but sometimes, yeah, it works." (002H, Pos. 112-115)

Collaborations of UNESCO with international institutions such as the Princeton Climate Institute contribute to the development of advanced early warning systems, leveraging technological advancements and scientific expertise. Overall, there is a need for continuous improvement in communication effectiveness and accessibility to bolster disaster preparedness and response mechanisms.

> "…the effectiveness will depend on the type of stakeholders on the ground. For instance, with your farming communities, because firstly, they rely on these rivers for watering their crops and so forth, their response will be quicker than just ordinary members of the communities communicating maybe the message through radio and so forth, because people tend to want to see things before they could believe seeing things…from the industries, it would be a quick response, because probably of the loss that could come as a result of that. But for ordinary communities, people only believe when they see something happening, not before it happens. So, sometimes that can also be linked to the trust that people have to either government institutions and so forth." (021U, Pos. 116-120)

II.6.3.2.2. Self-efficacy

From collated responses, there is considerable variation in the level of self-efficacy for the protection of heritage sites through disaster preparedness and response. Some respondents demonstrated a high level of self-efficacy, indicating a proactive approach towards capacity building and disaster preparedness. For instance, a respondent stated that “The capacity is very high in terms of the training.” (011H, Pos. 122). Another participant says “The fact that I've been to Europe, I've seen a lot of areas where I need to be transformed.” (007H, Pos. 233).

Meanwhile, other respondents mentioned attending various short courses, training programs and workshops, both domestically and internationally, focused on disaster risk management, conservation, and related fields. These efforts reflect a strong commitment to enhancing skills and knowledge in disaster response and mitigation. Conversely, other respondents mention the lack of capacity and dedicated staff trained in disaster risk management and significant gaps in resources and support.

> “So we do a lot of capacity building workshops with our stakeholders, but not necessarily to say, they're not competent. But, you know, a very strong element that is coming out in the work that we do is that of indigenous knowledge systems...the capacity building that is done is not necessarily that people are not competent, but just maybe showing more other alternatives or alternative approaches to adaptation.” (006H, Pos. 37, 39)

> “If there is a fire, we are not prepared to manage it. We need people to come and train us to manage forest fires if it ever happens to us. If there is an earthquake, we need people to train us to manage earthquakes if it ever happens to us. Floods, have we been trained to manage floods? No. So I think there's a problem of capacity, whether it's financial or technical, to preserve us from the catastrophes that will occur on the site.” (008H, Pos. 55-56)

> “There's need for specific or special training in terms of disaster risk management and all that. Well-organized trainings in terms of how they can manage disasters, how they can prepare for disasters, response, and post-disaster risk assessment and also activities that would help build resilience in the communities, issues of climate change. Yeah, and even detailed trainings about specific areas that are affected...we should have more officers that are able to do wildlife issues for the birds and also best agricultural practices, water management, environmental management, land forestry and all that. I think the numbers of people that have the required competence in this area, their numbers is also not enough, so we cannot cover the area well.” (002H, Pos. 97-98)

Challenges such as limited resources, including funding and technical expertise, were frequently highlighted. Also, despite attending training programs, some respondents expressed concerns about the adequacy and accessibility of these initiatives, suggesting that they may not be comprehensive or frequent enough to address the complex challenges posed by disasters effectively.

> "...looking at the frequency, I think UNESCO can provide a little more funding for such trainings to be held. Because they are held at the central level, but if they could also be held in the districts, if they could also be decentralized, and not only at the central government level." (016U, Pos. 153)

> "...some biosphere reserves may not have dedicated staff who are trained in disaster risk management. So, it's not a matter of how good they are. It's a matter of whether they're there at all." (017U, Pos. 115)

> "I attended a workshop last week in Cape Town, where there were a lot of models on early warning systems. I could understand them, but they were not in a form that an ordinary citizen who needed the information could understand." (016U, Pos. 205)

Therefore, indications of disparities in self-efficacy levels are reflected in pockets of high self-efficacy and proactive engagement in disaster risk reduction efforts, with a general clear call for more frequent, comprehensive, and accessible training programs, increased resources, and improved coordination among stakeholders across UNESCO-designated sites in Africa.

II.6.3.2.3. Response costs

We find an array of challenges associated with resource sufficiency for disaster preparedness and management within UNESCO-designated sites in Africa. Responding UNESCO actors provided insights into the sufficiency of required resources for disaster preparedness and management on sites, revealing significant challenges posed by financial constraints and resource limitations. A respondent succinctly replies that "preparedness is not that much, probably because of lack of resources, of financial resources" (002H, Pos. 48). Funding shortages, misappropriation, budget cuts, and difficulties in mobilizing resources hinder capacity-building initiatives, undermining essential measures such as information management and infrastructure maintenance. For example, a respondent states:

> "What the money is meant for, to me, I would say it's not being used effectively for what it's worth. Because as I'm speaking with you now, I am not happy. Looking at my effort to protect that place, looking at my effort to conserve that place...the money that was meant to do the work is not even coming" (007H, Pos. 259-260).

Insufficient governmental support and funding reflects a predominant focus on humanitarian aspects in disaster management in Africa, with insufficient attention given to disasters' impact on heritage and the environment, highlighting a critical gap.

> "There hasn't been a lot of focus on disasters and heritage, disasters, and environment and all that, so this is an area perhaps I think we can do more, and I believe that through engaging our policymakers we can make that become really a priority in all the interventions. So that is, the interventions are all rounded, not just focusing on people but also focusing on the heritage because if we lose some of this heritage, we will have lost the entire, and some of this heritage is key" (004U, Pos. 51).

Infrastructure limitations and communication barriers further compound the challenges associated with response costs in disaster preparedness. Lack of reliable communication infrastructure hampers coordination and response efforts during emergencies, worsening difficulties in accessing adequate information across African sites. For instance, the lack of sex-disaggregated data on vulnerable groups presents a need for more comprehensive data collection and analysis to better understand vulnerability dynamics for enhanced disaster preparedness. In addition, the absence of Geographic Information System (GIS) data complicates disaster management efforts. However, the potential for community mapping initiatives to address this challenge shows the importance of community engagement and symbolic appropriation of heritage properties.

> "...getting GIS data in Africa is not as easy as it could have been, for example, in Europe or North America. But on the other hand, it opens the door to working with, for example, community mapping. So, getting communities involved in, for example, GPS demarcation of the limits of the property can lead to getting very good quality GIS data, but most importantly, getting the communities involved in, well, not only in the mapping, but also, in a way, in the symbolic appropriation of the property" (003U, Pos. 30-31).

Another recurring theme across responses was the shortage of human resources and the imperative for capacity enhancement to effectively manage disaster risks. A respondent rhetorically asks, “I have just two staff with me. How do you expect me to manage it effectively?” (007H, Pos. 226). Another one complained, “I ought to have around 105 staff. But right now, we are only 65. Then you see the gap. It seems like a half-staff that I have. So, we are facing that first problem. The second one is money” (008H, Pos. 113-115).

Shortage of staff compromises response efforts, particularly in remote or challenging terrains where access is limited. Specifically, as a respondent asserts, “when we have less members of staff in a particular station, then that in itself compromises the ability for preparedness, as well as the ability for managing a disaster when it occurs” (004U, Pos. 110). Another focal person explains that “we do not have a well-established strategy to address these risks. We do what we can do when these disasters happen” (020U, Pos. 36).

While UNESCO provides support and capacity-building initiatives, there is a need for countries to prioritize risk management and invest in human resources to effectively manage and protect heritage sites. Such prioritization will be noticeable in addressing financial, infrastructural, and human resource constraints to enhance disaster resilience transcending the humanitarian scope to safeguard heritage and environment in the region.

II.6.3.3. Summary of responses

Table II.6–2 provides a concise summary of responses to elements of the protection motivation theory and levels of disaster preparedness. Most respondents, comprising over two-thirds of the sample, expressed high levels of perceived severity, vulnerability, and response efficacy. This suggests a heightened risk perception and a strong confidence in the effectiveness of implemented risk reduction measures. Conversely, approximately half of the participants reported low levels of self-efficacy, coupled with only partial disaster preparedness, indicating a direct correlation between perceived capability and readiness for disasters. Notably, while an equal number of respondents reported low self-efficacy and partial preparedness, some individuals expressed confidence in their abilities yet fell short in terms of overall preparedness. Additionally, nearly all respondents indicated low to moderate levels of response costs, highlighting inadequate human, material, and financial resources allocated to managing disaster risks at African UNESCO-designated sites.

II.6.3.4. Expressed protection motivation

Aside from presenting proxy questions to assess different components of the PMT, respondents were asked about their motivation for reducing disaster risks on sites. Some respondents clearly articulated a personal motivation for the protection of their UNESCO-designated sites, with their responses unveiling factors outside the PMT (Figure II.6–4). One significant motivation is the recognition of the invaluable cultural and environmental significance of these sites, prompting proactive measures to safeguard them from potential disasters. For instance, one respondent emphasized the importance of protecting heritage sites for future generations, stating, "I look at the future of the forest for the generations to come. Not, you know, sacrificing the forest today and how the younger generation will survive tomorrow" (007H, Pos. 64). This forward-looking perspective underscores a sense of responsibility towards preserving cultural and natural heritage for the benefit of posterity and sustainability.

Another respondent posits:

> "Really, I can't think of anything more important than linking existing ecosystems...Because we've damaged so many ecosystems and we've fragmented so many of them, I think, you know, if we're hoping for future generations to have a meaningful, a valuable life on Earth...if the fabric of those ecosystems isn't being fixed, I mean, already it's damaged. So, my personal motivation is a strong emphasis on restoring degraded ecosystems in between the protected areas" (019H, Pos. 52-53).

Moreover, the involvement of UNESCO in heritage preservation projects enhances community acceptance and cooperation, contributing to the sustained protection of these sites. As articulated by a participant, UNESCO interventions lead to increased acceptance among local communities, who perceive tangible benefits from project implementation: "when UNESCO comes up with a project, then implementation of the project is involved. Capacity building is involved. So, these are the motivations we take to keep the forest going in conserving the area" (011H, Pos. 103). This highlights the role of external support in fostering community engagement and garnering local support for conservation efforts.

Additionally, the desire to mitigate the adverse effects of disasters on heritage sites and surrounding ecosystems serves as a driving force behind UNESCO actors' protection initiatives. Respondents underscored the importance of disaster risk management in preserving heritage, acknowledging the multifaceted impacts of disasters on both human lives and biodiversity. Specifically, one respondent highlighted the catastrophic consequences of disasters on heritage sites. He highlighted the irreplaceable nature of cultural heritage and the urgency of disaster preparedness and mitigation efforts as follows:

"Some of them have a heritage that if exposed to a disaster you end up losing the entire heritage, you cannot get it back, you really can't get it back and so that motivates me to have an interest in disasters from both an anthropogenic point of view to economic to conservation point of view..." (004U, Pos. 46).

Table II.6–2: Overview of protection motivation and disaster preparedness

Code	Site Type	Perceived severity	Vulnerability perception	Fear	Response efficacy	Self-efficacy	Response costs	Expressed Preparedness
001H	WHS	High	High	Stress	Moderate	Moderate	Low	Prepared
002H	BR	High	High	Desperation	Moderate	Low	Low	Partially prepared
003U	UNESCO	Moderate	Moderate	None	High	High	Low	Partially prepared
004U	NATCOMM	High	High	None	High	Low	Low	Poorly prepared
005U	UNESCO	High	High	None	High	High	Low	Poorly prepared
006H	BR	Moderate	High	None	High	Moderate	Moderate	Partially prepared
007H	BR	High	High	None	Low	Low	Low	Poorly prepared
008H	BR	Moderate	High	Displeasure	High	Low	Low	Poorly prepared
009H	BR	Moderate	Moderate	None	Moderate	Low	Moderate	Partially prepared
010H	BR	High	High	None	Low	Low	Low	Partially prepared
011H	BR	Moderate	Moderate	None	High	High	Low	Prepared
012H	WHS	High	High	None	High	High	Moderate	Prepared
013U	UNESCO	High	High	None	High	Moderate	High	Prepared
014U	UNESCO	High	High	None	High	High	Moderate	Partially prepared
015H	BR	High	High	None	High	Low	Low	Poorly prepared
016U	NATCOMM	High	High	None	High	Low	Low	Partially prepared
017U	UNESCO	High	High	None	High	Moderate	Moderate	Partially prepared
018H	BR	High	High	None	High	Low	Low	Poorly prepared
019H	BR	High	High	None	High	High	Low	Partially prepared
020U	NATCOMM	High	High	None	Low	Low	Low	Poorly prepared
021U	NATCOMM	High	High	None	High	High	Moderate	Partially prepared
Overall rating		High	High	Low	High	Low	Low	Partially prepared

Note: The overall rating for the entire group in Table II.6–2 was derived by evaluating the frequency of individual responses for each of the tested components of the Protection Motivation Theory.

Furthermore, UNESCO actors are motivated by a sense of duty to promote sustainable development and resilience within local communities. By integrating disaster risk management into conservation strategies, UNESCO aims to enhance the resilience of communities and ecosystems to environmental hazards. As expressed by a respondent, efforts are directed towards capacity building and awareness raising to empower communities to cope with disasters: "And for me, this is, you know, the most important thing. If our action can help, you know, on saving a life, so I think…we can be proud" (013U, Pos. 48). This response highlights the alignment of UNESCO's mission with broader development goals aimed at fostering sustainable livelihoods and protecting cultural and natural heritage.

Therefore, we derived two data-driven factors related to protection motivation and disaster preparedness, which expand upon the elements of the Protection Motivation Theory. These factors are heritage stewardship and sustainability or resilience commitment. Heritage stewardship, as defined by Brown and Mitchell (1998), entails a holistic approach aimed at fostering individual and community responsibility, both publicly and privately, for the sustainable management and protection of natural and cultural heritage resources. Additionally, sustainability commitment entails the willingness and capacity to actively contribute to the ongoing transformation towards a sustainable future for our world (Öhman & Sund, 2021).

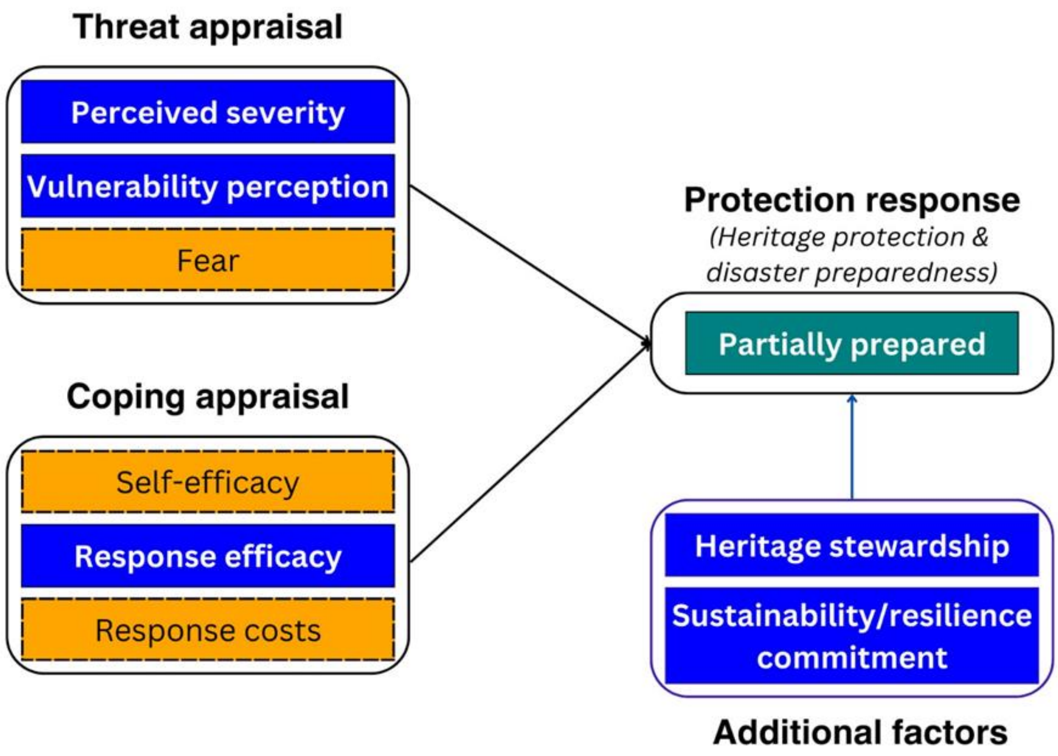


Figure II.6–4: Data-driven extension of the protection motivation theory from this study

II.6.4. Discussion

This qualitative study highlights the dynamics of critical protection motivation factors and disaster preparedness on African UNESCO-designated sites. By exploring the elements of the PMT alongside personal motivations driving disaster preparedness and conservation initiatives, we contribute to the discourse on disaster risk reduction and heritage preservation in vulnerable regions such as Africa. Threat appraisal concerns are juxtaposed with contemporary climate change issues underscoring the need for comprehensive risk management strategies, focusing on both natural and human-induced hazards.

Previous studies have identified anthropogenic interferences as potential threats to UNESCO-designated sites. Dulias (2022) not only identified human activities threatening sites but expressed concerns regarding law enforcement, sustainable financing, staff capacity, training, and development among others coinciding with elements of threat and coping appraisal factors of protection motivation identified in this study. Governance mechanisms and law enforcement to address illegal activities should be strengthened to curb environmental degradation and heritage hazard exposure through human-induced hazards, which respondents have enumerated as indiscriminate deforestation, wildfires, hunting and the like.

Moreover, corresponding critical infrastructure development for targeted capacity development and increased coping capacity of host communities is also required.

Although some stakeholders perceive disaster impacts as primarily humanitarian, affecting livelihoods and local communities, others emphasize the significant and multifaceted impacts of disasters on some OUV elements of UNESCO-designated sites. Disaster risk reduction strategies that prioritize the conservation and protection of the environment alongside humanitarian concerns require more attention in budgeting, planning, policies, and actions. This is in line with an earlier recommendation of Eze and Siegmund (2024), who prescribed collaborative initiatives involving local communities to comprehensively address the complex dynamics of disaster resilience and sustainable development in Africa.

The consensus that additional efforts are needed to effectively address current environmental threats and enhance coping mechanisms within UNESCO-designated sites indicates a recognition of the ongoing challenges and the need for sustained and coordinated action to mitigate disaster risks and build resilience in these vulnerable areas. To achieve disaster preparedness and resilience, host communities must be integrated into the decision-making process. It is imperative, therefore, to reverse the reliance on the government, which Nahayo et al (2017) argue could overshadow the incorporation of traditional knowledge from local communities, potentially diminishing disaster resilience and preparedness. Moreover, while existing initiatives, such as empowerment programs and early warning systems, show promise, persistent challenges, including limited funding and technical expertise, underscore the imperative of sustained action.

Given our findings, we recommend that tailored approaches to capacity building and disaster preparedness consider the specific context and challenges of each site. Also, we argue that the effectiveness of disaster risk reduction initiatives, including early warning systems, relies on stakeholders' belief in the efficacy of recommended actions. These interconnected issues have been earlier listed by the study of Lumbroso (2018), which advocated for adequate funding to ensure an efficient early warning system that could be trusted by Africans. Effective warning systems are both life- and cost-saving measures that foster trust and confidence in personal safety (Golding, 2022). Assessments such as regular surveys and personal interviews are recommended by Scolobig et al (2022), especially after warnings, to identify concerns and reinforce positive changes, thus building trust. Hence, timely dissemination of accurate information, the availability of human, material and financial resources for response and mitigation, and trust-building in governmental and organizational efforts are necessary for protection motivation and disaster preparedness.

Fear emerged as a significant non-supporting factor of protection motivation and disaster preparedness in our study. This finding stems from the responses to the questions in Table 2, where fear appeals were notably absent. Tannenbaum et al.

(2015) describe fear appeals as persuasive messages intended to evoke fear by emphasizing the potential danger and harm individuals might face if they ignore recommended actions. Since we did not directly assess the fear levels of UNESCO actors using fear appeals, caution is advised when interpreting our findings. Furthermore, other elements of threat appraisal, such as hazard and vulnerability perception, which were already rated highly, could indirectly induce fear as a factor in disaster preparedness. For example, studies by Weinstein (1989), de Boer et al. (2015), and Quan et al. (2017) indicate that disaster experiences contribute to the expression of threat appraisal elements, including vulnerability perception and fear, which in turn influence preparedness behaviors.

These studies agree that disaster experiences coupled with insufficient preparedness can instill a fear of recurrence, prompting actions to improve future preparedness. Additionally, while some participants expressed concerns about the irreversible damage to heritage sites—an indication of some level of fear—our study did not deeply investigate previous disaster experiences and their impact on fear, limiting the depth of our findings in this area. Furthermore, given that our respondents are scientifically informed, they are less likely to express fear compared to community members in the same setting.

Moreover, besides the PMT components, UNESCO actors protect heritage sites in Africa driven by a sense of stewardship towards cultural and environmental treasures, community engagement and support facilitated by project interventions, recognition of the vulnerability of heritage to disasters, and a commitment to promoting sustainable development and resilience. The two elements – vulnerability recognition and supportive project intervention align with the threat and coping appraisal components of the PMT, thus affirming PMT as a factor of disaster preparedness on UNESCO-designated sites.

However, the concept of place attachment, defined as the bond between persons, processes, and places by Mishra et al (2010) and Scannell & Gifford (2010), which could potentially elucidate the affective and behavioural aspects of respondents' heritage stewardship and sustainability-resilience commitments, was not incorporated into the design of this study. Place attachment has been found to relate to disaster preparedness in previous studies such as Wallis et al (2022), Wang et al (2021); Mishra et al (2010). Therefore, place attachment should be integrated into the PMT in future studies for robust testing.

II.6.5. Conclusion

This qualitative study sought to determine the supporting and non-supporting factors of protection motivation of UNESCO actors based on the PMT. Perceptions of the severity of and vulnerability to hazards, as well as response efficacy, were highly expressed among respondents in contrast to fear, self-efficacy, and response costs. Thus, although threat appraisal was high among respondents, the coping appraisal was low, coupled with partial disaster preparedness among UNESCO actors. While we reaffirm the significance of governance improvements in combating environmental degradation and human-induced hazards, we argue for balancing humanitarian-focused disaster risk management and environmental conservation within the context of UNESCO-designated sites. Notably, the absence of fear as a predominant motivating factor was compensated by UNESCO actors' strong sense of heritage stewardship, and their sustainability/resilience commitment. These emergent motivators, which stand as a unique contribution by our study, expand the conceptual boundaries of PMT, highlighting the multidimensional nature of heritage protection and disaster preparedness.

Therefore, future research should explore the integration of elements from place attachment theory into PMT, thereby offering a more comprehensive understanding of heritage protection motivation dynamics. Furthermore, aspects such as assessing the impact of disaster risk reduction policies and plans, exploring indigenous knowledge systems, and analyzing funding models of heritage sites warrant more comprehensive investigations in future studies, as they fall outside the scope of this paper. By leveraging the insights from our study, policymakers, practitioners, and stakeholders can collaboratively strive towards the sustainable preservation of Africa's rich cultural and natural heritage for generations to come through the improvement of protection and disaster preparedness.

II.6.6. References

American Psychological Association (2016). *Ethical principles of psychologists and code of conduct*. https://www.apa.org/ethics/code/ethics-code-2017.pdf

Brown, J. L., & Mitchell, B. A. (1998). Stewardship: a working definition. *Environments: A Journal of Interdisciplinary Studies*, 26(1), 8.

Bündnis Entwicklung Hilft & Institute for International Law of Peace and Armed Conflict (IFHV), (2023). *WeltRisikoBericht 2023*. Berlin: Bündnis Entwicklung Hilft.

De Boer, J., Wouter Botzen, W. J., & Terpstra, T. (2015). More than fear induction: Toward an understanding of people''s motivation to be well-prepared for emergencies in flood-prone areas. *Risk analysis*, 35(3), 518-535. https://doi.org/10.1111/risa.12289

Dulias, R. (2022). Anthropogenic and natural factors influencing African World Heritage sites. *Environmental & Socio-economic Studies*, 10(3), 67-84. https://doi.org/10.2478/environ-2022-0018

Durrant, L. J., Vadher, A. N., & Teller, J. (2023). Disaster risk management and cultural heritage: The perceptions of European world heritage site managers on disaster risk management. *International journal of disaster risk reduction*, 89, 103625. https://doi.org/10.1016/j.ijdrr.2023.103625

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of advanced nursing*, 62(1), 107-115. https://doi.org/10.1111/j.1365-2648.2007.04569.x

Eze, E., & Siegmund, A. (2024a). Identifying disaster risk factors and hotspots in Africa from spatiotemporal decadal analyses using INFORM data for risk reduction and sustainable development. *Sustainable Development.* 1 – 22. https://doi.org/10.1002/sd.2886

Eze, E., & Siegmund, A. (2024b). Appraising competency gaps among UNESCO-designated heritage site actors in disaster risk reduction innovations. *Progress in Disaster Science*, 22, 100321 https://doi.org/10.1016/j.pdisas.2024.100321

Eze, E., & Siegmund, A. (2024c). Exploring factors of disaster preparedness in UNESCO-designated heritage sites, *Geography and Sustainability*, 5, 392 – 404, https://doi.org/10.1016/j.geosus.2024.04.001

Faryabi, R., Davarani F. R., Daneshi S., & Moran, D.P. (2023). Investigating the effectiveness of protection motivation theory in predicting behaviors relating to natural disasters, in the households of southern Iran. *Frontiers in public health*, 11, 1201195. https://doi.org/10.3389/fpubh.2023.1201195

Golding, B. (2022). Introduction. In *Towards the "Perfect" Weather Warning: Bridging Disciplinary Gaps through Partnership and Communication* (pp. 47-85). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-98989-7

Graham, K., & Spennemann, D. H. (2006). Heritage managers and their Attitudes towards Disaster Management for cultural heritage resources in New South Wales, Australia. *International Journal of Emergency Management*, 3(2-3), 215-237. https://doi.org/10.1504/IJEM.2006.011169

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative health research*, 15(9), 1277-1288. https://doi.org/10.1177/1049732305276687

Lumbroso, D. (2018). How can policy makers in sub-Saharan Africa make early warning systems more effective? The case of Uganda. *International journal of disaster risk reduction*, 27, 530-540. https://doi.org/10.1016/j.ijdrr.2017.11.017

Mishra, S., Mazumdar, S., & Suar, D. (2010). Place attachment and flood preparedness. *Journal of environmental psychology*, 30(2), 187-197. https://doi.org/10.1016/j.jenvp.2009.11.005

Nahayo, L., Mupenzi, C., Kayiranga, A., Karamage, F., Ndayisaba, F., Nyesheja, E. M., & Li, L. (2017). Early alert and community involvement: approach for disaster risk reduction in Rwanda. *Natural hazards*, 86, 505-517. https://doi.org/10.1007/s11069-016-2702-5

Öhman, J., & Sund, L. (2021). A didactic model of sustainability commitment. *Sustainability*, 13(6), 3083. https://doi.org/10.3390/su13063083

Olmos-Vega, F. M., Stalmeijer, R. E., Varpio, L., & Kahlke, R. (2023). A practical guide to reflexivity in qualitative research: AMEE Guide No. 149. *Medical teacher*, 45(3), 241-251. https://doi.org/10.1080/0142159X.2022.2057287

Pavlova, I., Fassoulas, C., Watanabe, M., Canet, C., & Cupa, P. (2019). *UNESCO designated sites—natural and cultural heritage sites as platforms for awareness raising*. Contributing paper to GAR.

Pavlova, I., Makarigakis, A., Depret, T., & Jomelli, V. (2017). Global overview of the geological hazard exposure and disaster risk awareness at world heritage sites. *Journal of Cultural Heritage*, 28, 151-157. https://doi.org/10.1016/j.culher.2015.11.001

Quan, L., Zhen, R., Yao, B., Zhou, X., & Yu, D. (2017). The role of perceived severity of disaster, rumination, and trait resilience in the relationship between rainstorm-related experiences and PTSD amongst Chinese adolescents following rainstorm disasters. *Archives of psychiatric nursing*, 31(5), 507-515. https://doi.org/10.1016/j.apnu.2017.06.003

Rockmann, K. W., & Vough, H. C. (2023). Using Quotes to Present Claims: Practices for the Writing Stages of Qualitative Research. *Organizational Research Methods*, 1–29. https://doi.org/10.1177/10944281231210558

Rogers, R. W. (1975). A protection motivation theory of fear appeals and attitude change1. *The journal of psychology*, 91(1), 93-114. https://doi.org/10.1080/00223980.1975.9915803

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., Burroughs, H. & Jinks, C. (2018). Saturation in qualitative research: exploring its conceptualization and operationalization. *Quality & quantity*, 52, 1893-1907. https://doi.org/10.1007/s11135-017-0574-8

Scannell, L., & Gifford, R. (2010). Defining place attachment: A tripartite organizing framework. *Journal of Environmental Psychology*, 30(1), 1–10. https://doi.org/10.1016/j.jenvp.2009.09.006

Scolobig, A., Potter, S., Kox, T., Kaltenberger, R., Weyrich, P., Chasco, J., ... & Rana, B. (2022). Connecting warning with decision and action: A partnership of communicators and users. In *Towards the "Perfect" Weather Warning: Bridging Disciplinary Gaps through Partnership and Communication* (pp. 47-85). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-98989-7

Tang, J. S., & Feng, J. Y. (2018). Residents' disaster preparedness after the Meinong Taiwan earthquake: A test of protection motivation theory. *International Journal of Environmental Research and Public Health*, 15(7), 1434. https://doi.org/10.3390/ijerph15071434

Tannenbaum, M. B., Hepler, J., Zimmerman, R. S., Saul, L., Jacobs, S., Wilson, K., & Albarracín, D. (2015). Appealing to fear: A meta-analysis of fear appeal effectiveness and theories. *Psychological bulletin*, 141(6), 1178. http://dx.doi.org/10.1037/a0039729

VERBI Software. (2021). *MAXQDA 2022* [computer software]. Berlin, Germany: VERBI Software. Available from maxqda.com.

Wallis, A., Fischer, R., & Abrahamse, W. (2022). Place attachment and disaster preparedness: Examining the role of place scale and preparedness type. *Environment and Behavior*, 54(3), 670-711. https://doi.org/10.1177/00139165211064196

Wang, Z., Han, Z., Liu, L., & Yu, S. (2021). Place attachment and household disaster preparedness: Examining the mediation role of self-efficacy. *International journal of environmental research and public health*, 18(11), 5565. https://doi.org/10.3390/ijerph18115565

Weinstein ND. Effects of personal experience on self-protective behavior (1989). *Psychological Bulletin*, 105:31–50. https://psycnet.apa.org/doi/10.1037/0033-2909.105.1.31

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4. **Beteiligungen/*Contributions*****

Contributor Role	Doktorand/in/ *Doctoral student*	Co-Autor/in 1/ *Co-author 1*	Co-Autor/in 2/ *Co-author 2*
Name, first name	Eze, Emmanuel	Siegmund, Alexander	Petersen, Maike
Methodology	✓		
Software			
Validation			
Formal analysis	✓		
Investigation	✓		
Resources	✓	✓	
Data Curation	✓		
Writing-Original Draft	✓		
Writing-Review&Editing	✓	✓	✓
Visualization	✓		
Supervision		✓	
Project administration	✓	✓	✓
Funding acquisition	✓		

***Kategorien des CRediT (Contributor Roles Taxonomy, https://credit.niso.org/)*

Hiermit bestätige ich, dass alle obigen Angaben korrekt sind/*I confirm that all declarations made above are correct.*

Unterschrift/*Signature* [signature] Doktorand/in/*Doctoral student* [signature] Co-Autor/in 1/*Co-author 1* [signature] Co-Autor/in 2/*Co-author 2*

Betreuungsperson/*Supervisor*:
Hiermit bestätige ich, dass alle obigen Angaben korrekt sind und dass die selbstständigen Arbeitsanteile des/der Doktoranden/in an der aufgeführten Publikation hinreichend und signifikant sind/*I confirm that all declarations made above are correct and that the doctoral student's independent contribution to this publication is significant and sufficient to be considered for the cumulative dissertation.*

Alexander Siegmund — Name/*Name*
[signature] — Unterschrift/*Signature*
29.07.2024 — Datum/*Date*

Appendices

Appendix 1a: Approved self-assessment ethics form for this study

Gemeinsame Ethikkommission der Pädagogischen Hochschule Heidelberg und der SRH Hochschule Heidelberg

Bestätigung der Durchführung einer ethischen Selbstüberprüfung[1]

Name des/der Forschenden
Prof. Dr. Alexander Siegmund
Dienstanschrift (mit Angabe der Fakultät)
Abteilung Geographie, Institut für Naturwissenschaften, Geographie und Technik, Pädagogische Hochschule Heidelberg, Fakultät III
Titel des Forschungsvorhabens
Core competencies and actionable early warning messages for effective disaster risk reduction in Africa

Erklärung des/der Forschenden:

Ich habe die forschungsethische Selbstüberprüfung der gemeinsamen Ethikkommission der Pädagogischen Hochschule Heidelberg und der SRH Hochschule Heidelberg wahrheitsgemäß und auf Grundlage der Guten Wissenschaftlichen Praxis ausgefüllt.

Heidelberg, 26.10.2023

Ort, Datum　　　Unterschrift

Bestätigung durch den Vorsitzenden der gemeinsamen Ethikkommission:

Der Vorsitzende der gemeinsamen Ethikkommission bestätigt hiermit, dass der bzw. die Forschende das oben benannte Forschungsvorhaben der forschungsethischen Selbstüberprüfung der Pädagogischen Hochschule Heidelberg und der SRH Hochschule Heidelberg unterzogen hat.

HD, 31.10.23

Ort, Datum　　　Prof. Dr. Alexander Siegmund

[1] Angelehnt an die Deutsche Gesellschaft für Sozial- und Kulturanthropologie: https://www.dgska.de/dgska/ethik/ [April 2023].

Stand: 07/2023

Appendix 1b Approved ethics for this study

Gemeinsame Ethikkommission der Pädagogischen Hochschule Heidelberg und der SRH Hochschule Heidelberg

Herr Prof. Dr. Siegmund
Pädagogische Hochschule Heidelberg
Abteilung Geographie,
Institut für Naturwissenschaften,
Geographie und Technik
Czernyring 22/10-12
69115 Heidelberg

z.K. Herr Emmanuel Eze

Der Vorsitzende der Gemeinsamen Ethikkommission der Pädagogischen Hochschule Heidelberg und der SRH Hochschule Heidelberg

Prof. Dr. Alexander Siegmund

Pädagogische Hochschule Heidelberg
Raum 206b (Altbau),
Keplerstr. 87
69120 Heidelberg

Heidelberg, den 09.02.2024/01

Ethikvotum EV2024_01 zu Ihrem Antrag vom 27.11.2023

Sehr geehrter Herr Siegmund,

zu Ihrem Antrag auf ein Ethikvotum zum Forschungsvorhaben „Core competencies and actionable early warning messages for effective disaster risk reduction in Africa" haben die Mitglieder der Gemeinsamen Ethikkommission der Pädagogischen Hochschule Heidelberg und der SRH Hochschule Heidelberg auf der Grundlage Ihres Antrags mehrheitlich ein positives Votum gefasst.

Für Ihr Forschungsprojekt wünsche ich Ihnen gutes Gelingen.

Mit freundlichen Grüßen

I.V.

(Prof. Dr. Karl-Heinz Dammer)

Appendix 2: Questionnaire used for the survey conducted in this study

Core competencies, knowledge and behaviours of UNESCO sites' actors for disaster risk management

Kind request to complete a questionnaire for my doctoral research

Dear participant,

Thank you for your interest in my research and your willingness to assist me in providing pertinent data for this crucial research.

I am Emmanuel Eze, a doctoral researcher at the University of Heidelberg, Germany. My thesis is focused on identifying core competencies, knowledge, and behaviours of UNESCO sites' actors for disaster risk management. This research will identify the current competencies, knowledge, and actions of different categories of actors within UNESCO sites and unveil needs for further training, which will create future scientific funding opportunities to address these needs.

This survey will take you no more than 25 minutes to complete and your responses are completely confidential. The questions are drafted with the intention of making your responses unidentifiable, so please do not enter any identifying information in the text boxes.

The collected data will be stored securely in the server of my university and accessible to the researcher alone. Your responses will be evaluated ONLY for scientific research purposes. The overall findings from the analyses of the questionnaire will be used to develop my PhD thesis. These findings will be shared with UNESCO through the online Open Learning platform, presented at academic conferences, published in scientific journals and/or used for funding applications for necessary implementations to further developments in the UNESCO sites.

Some demographic information is included to provide a deeper understanding of additional factors that may yield various results. Also, some questions about your previous experiences with disaster may cause some discomfort.

The request for your email address will be used strictly to establish further contacts in the next stage of this thesis. Also, I would like to share the findings of the study with you as well as training opportunities in disaster risk management.

Should you have further questions or concerns to be clarified before responding to the survey, kindly contact me or my supervisor by email at the addresses provided below.

Again, I thank you for considering participation in this research.

Emmanuel Eze - *Doctoral Researcher* (emmanuel.eze@ph-heidelberg.de)
Professor Dr Alexander Siegmund - *Scientific Supervisor* (siegmund@ph-

heidelberg.de)
Department of Geography, Research Group for Earth Observation (rgeo)
UNESCO Chair of Earth Observation and Geocommunication of World Heritage Sites and Biosphere Reserves

* 1. I have read the information above and hereby give my consent to participate in this research. By participating, I confirm that I am over the age of 18. I also understand that my responses will be kept anonymous and confidential.

- [ ] Yes, I agree to participate
- [ ] No, I do not want to participate

2. I would like to share the findings of my study and related training opportunities with you, please enter your email address (optional)

* 3. Which of these options best describes the UNESCO site where you work?

- [ ] World Heritage: cultural site
- [ ] World Heritage: natural site
- [ ] World Heritage: mixed site
- [ ] Biosphere reserve
- [ ] Geopark
- [ ] Other (please specify)

4. What is the name of the UNESCO site you work in/oversee?

* 5. In what country is this UNESCO site located?

* 6. What is your role in the UNESCO site?

- ○ UNESCO site staff (junior)
- ○ UNESCO site staff (senior)
- ○ UNESCO site manager
- ○ UNESCO National commission supervisory staff
- ○ UNESCO Supervisory staff
- ○ Other (please specify)

RESEARCH GROUP FOR EARTH OBSERVATION

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UNESCO-Lehrstuhl für Erdbeobachtung und Geokommunikation von Welterbestätten und Biosphärenreservaten Pädagogische Hochschule Heidelberg

Core competencies, knowledge and behaviours of UNESCO sites' actors for disaster risk management

Frequency and consequences of natural disasters on UNESCO sites

Disasters are "*unforeseen and often sudden events that cause great damage, destruction and human suffering. Though often caused by nature, disasters can have human origins.*" (CRED, 2022)

We present a list of disasters from the Emergency Events Database (EM-DAT) maintained by the Centre for Research on the Epidemiology of Disasters (CRED).

* 7. How frequently do these natural disasters occur on or around your site?

	Frequently – more than once in 5 years	Regularly – more than once in 10 years	Occasionally – once in 10 years	Rare – once in 100 years	Very rare – once in over 1000 years	Never occurred on my site	Not relevant/cannot occur on my site location
Ground movement (Earthquake)							
Tsunami							
Rock fall							
Landslide (dry)							
Landslide (avalanche of snow, debris or mudflow)							
Volcanic activity							
Extreme cold wave							
Extreme heat wave							
Severe winter conditions							
Dense Fog							
Extra-tropical storm e.g., cyclones, blizzards							
Tropical storm e.g., hurricanes							
Convective Storm e.g., tornadoes							
Flood							
Destructive wave actions							
Drought							
Glacial Lake Outburst							
Forest Fire							
Land fire of Brush/bush/Pasture							
Violent conflicts/wars/riots/unrest/protest							

Other (please specify)

* 8. Disasters have consequences when they occur. Kindly indicate the level of agreement on the likely impact of future occurrence of disasters on or around your UNESCO site.

	Extremely unlikely	Unlikely	Neutral	Likely	Extremely likely
Damage to the property's outstanding universal value during emergency response activities					
Damage or pressure caused by displaced peoples camps, their infrastructure,					

waste and energy requirements					
Encroachment of people into the site	○	○	○	○	○
Pressure of illegal or uncontrolled development around the site	○	○	○	○	○
Injury, mortality, or displacement of staff can reduce the capacity for security, monitoring and enforcement	○	○	○	○	○
Loss of livelihood sources linked to the property	○	○	○	○	○
Stealing of cultural artifacts on the site	○	○	○	○	○
Enhanced rate of deterioration of damaged wood or stone	○	○	○	○	○
Risk of the loss of authenticity or of falsification through reconstruction	○	○	○	○	○
Water damage from firefighting	○	○	○	○	○
Unique values and integrity of the site is degraded through habitat loss and poaching	○	○	○	○	○
Pollution from waterborne debris and contaminated watercourses	○	○	○	○	○
Damage of site-level office buildings and equipment	○	○	○	○	○
Hazard-specific risks affect site level staff	○	○	○	○	○
Hurricanes and tornadoes on my site can lead to storm surge, which can cause flooding	○	○	○	○	○
Earthquakes on my site may cause a tsunami, fire, and landslides	○	○	○	○	○

Other (please specify)

* 9. Generally, the consequences of disasters in and around your site are:

no consequence	gradual (in stages)	mild	catastrophic/severe
◯	◯	◯	◯

Other (please specify)

* 10. What skills and resources are available for your use in managing adverse conditions, risks, or disasters on the site? *Multiple answers are possible*

- ☐ Emergency response staff
- ☐ Crisis communications staff
- ☐ Shelter space
- ☐ Emergency Operations Center
- ☐ Disaster detection systems
- ☐ Alarm/warning systems
- ☐ Maintained emergency exit routes
- ☐ Communication radios
- ☐ Wired telephone
- ☐ Smartphones
- ☐ Pagers/Beepers
- ☐ Fire extinguishers
- ☐ Personal protective equipment
- ☐ First aid materials

Other (please specify)

* 11. What specific conditions make individuals and your UNESCO site easily affected by the occurrence of a disaster? *Multiple answers are possible*

- ☐ Poor design and construction of buildings
- ☐ Poor land use planning
- ☐ Illegal settlements
- ☐ Poverty
- ☐ Disability
- ☐ Uninsured informal sector
- ☐ Dependence on a single means of livelihood
- ☐ Low income
- ☐ Poor environmental management
- ☐ Climate change
- ☐ Age: Older people suffer more
- ☐ Gender: Women suffer more
- ☐ Social status: illiterates suffer more
- ☐ None of the above

Other (please specify)

* 12. How much damage to your home or possessions have you or someone you know suffered in a past natural disaster?

None			Moderate amount of damages			A lot of damages
◯	◯	◯	◯	◯	◯	◯

* 13. Have you or someone you know been physically harmed in a past natural disaster?

- ◯ Yes
- ◯ No

If yes, briefly tell us about this event

* 14. Have you or someone you know been emotionally or mentally harmed in a past natural disaster?

◯ Yes

◯ No

If yes, briefly tell us about this event

* 15. Have you experienced natural events which didn't cause you harm or damage but made you feel scared or vulnerable?

◯ Yes

◯ No

If yes, briefly tell us about this event

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uniTwin Pädagogische Hochschule HEIDELBERG University of Education Geographie

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Core competencies, knowledge and behaviours of UNESCO sites' actors for disaster risk management

Core competencies for disaster risk management

There are core competencies required of UNESCO actors for effective disaster risk management on their sites. Some of these competencies could be acquired from participating in further training, workshops or short courses.

* 16. Have you attended any training, workshop or short course on disaster risk management?

◯ Yes: less than 5 years ago

◯ Yes: within the last 10 years

◯ Yes: between 10 - 20 years ago

◯ No, not at all

* 17. In which of the following modes will you prefer to learn about disaster risk management?

- ◯ Instructor-led training
- ◯ Coaching or mentoring
- ◯ Hands-on workshop
- ◯ In-person short courses
- ◯ Self-paced virtual courses
- ◯ Enrollment in an additional degree/diploma
- ◯ Other (please specify)

* 18. What is your level of competence or experience in the application of these recent innovations for disaster risk reduction?

	No level of competence/No experience	Low level of competence/Little experience	Average level of competence/Some experience	Moderately high level of competence/Good experience	Very High level of competence/Extensive experience	No answer
GIS and remote sensing	○	○	○	○	○	○
Unmanned aerial vehicles (drones)	○	○	○	○	○	○
Social Networking Services (SNS)	○	○	○	○	○	○
Concrete and steel: building material and infrastructure	○	○	○	○	○	○
Disaster risk insurance of persons and properties	○	○	○	○	○	○
Disaster prevention radio and telemetry system	○	○	○	○	○	○
Schools as cyclone shelter	○	○	○	○	○	○
Seismic code	○	○	○	○	○	○
Seismic micro zonation	○	○	○	○	○	○
Earthquake early warning	○	○	○	○	○	○
Doppler radar	○	○	○	○	○	○
Disaster resilient material	○	○	○	○	○	○
Rainwater harvesting	○	○	○	○	○	○
Electricity resistant survey	○	○	○	○	○	○

Your competence/Experience on other innovations not listed (please specify)

* 19. Kindly indicate your level of agreement with these statements

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
I possess critical thinking for problem identification and solutions	○	○	○	○	○	○	○
I demonstrate Professional ethics of respect, justice, integrity, and selfless service	○	○	○	○	○	○	○
I engage in continual learning and knowledge expansion	○	○	○	○	○	○	○
I consider all hazards, phases, stakeholders, and impacts relevant to disasters	○	○	○	○	○	○	○
I expect future disasters and develop disaster-resistant and disaster-resilient communities	○	○	○	○	○	○	○
I utilize sound risk management principles in assigning priorities and resources	○	○	○	○	○	○	○
I ensure unity of efforts among all community members to manage disaster risk	○	○	○	○	○	○	○
I create and sustain a team atmosphere to facilitate communication	○	○	○	○	○	○	○
I facilitate synchronous activities among all relevant stakeholders to achieve a common purpose	○	○	○	○	○	○	○
I use creative and innovative approaches in solving disaster challenges	○	○	○	○	○	○	○
I value a science and knowledge-based approach for continuous improvement	○	○	○	○	○	○	○
I consider, utilize, and value the							

growing body of disaster risk management literature for building disaster resilient communities	○	○	○	○	○	○	○
I appreciate scientific processes and how their applications benefits humanity	○	○	○	○	○	○	○
The world is made of physical, built, and social systems, which interact in multifaceted ways, producing varying levels of risk and vulnerability	○	○	○	○	○	○	○
People and places are connected in a dynamic network of global relationships	○	○	○	○	○	○	○
I help others understand the relationship between social factors and disaster risk concentration	○	○	○	○	○	○	○
I use existing appropriate technologies in disaster risk management practice	○	○	○	○	○	○	○
I consider ethical, legal, and social implications when determining appropriateness of a technology application for disaster risk management	○	○	○	○	○	○	○
I work in partnership with others and utilize a range of resources available within the system to establish an innovative solution to a pressing problem	○	○	○	○	○	○	○
I clearly communicate and explain hazard risks to a wide range of stakeholders	○	○	○	○	○	○	○
I understand and apply disaster risk management frameworks to	○	○	○	○	○	○	○

identify and manage risks							
I monitor, evaluate, and review risk management processes and outcomes	○	○	○	○	○	○	○
I involve the stakeholders to focus on the disaster risk exposure	○	○	○	○	○	○	○
I facilitate a community learning process through communications, dialogue, negotiation, and cooperation	○	○	○	○	○	○	○
I support community networks through ongoing improvement of collective disaster risk reduction goals and interventions	○	○	○	○	○	○	○
I identify and analyse a hazard risk issue for action	○	○	○	○	○	○	○
I analyse access to the relational dynamics of, and the ramifications from those in positions of political power, policy, and legal parameters in connection to disaster risk issues	○	○	○	○	○	○	○
I bring people together across sectors to identify and address disaster risk issues at hand	○	○	○	○	○	○	○
I inspire a shared vision with community stakeholders and involve them to contribute to its achievement	○	○	○	○	○	○	○
I empower my staff to successfully pursue our organisation's vision	○	○	○	○	○	○	○
I resolve conflicts that emerge within or between the organization and	○	○	○	○	○	○	○

the community it serves	

* 20. Some innovations for disaster risk reduction have emerged recently. What is the level of importance you assign to the listed innovations for disaster risk reduction?

	Not Important at All	Of Little Importance	Of Average Importance	Very Important	Absolutely Essential	Not applicable
GIS and remote sensing	○	○	○	○	○	○
Unmanned aerial vehicles (drones)	○	○	○	○	○	○
Social Networking Services (SNS)	○	○	○	○	○	○
Concrete and steel: building material and infrastructure	○	○	○	○	○	○
Disaster risk insurance of persons and properties	○	○	○	○	○	○
Disaster prevention radio and telemetry system	○	○	○	○	○	○
Schools as cyclone shelter	○	○	○	○	○	○
Seismic code	○	○	○	○	○	○
Seismic micro zonation	○	○	○	○	○	○
Earthquake early warning	○	○	○	○	○	○
Doppler radar	○	○	○	○	○	○
Disaster resilient material	○	○	○	○	○	○
Rainwater harvesting	○	○	○	○	○	○
Electricity resistant survey	○	○	○	○	○	○

Other innovations not listed (please specify)

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Core competencies, knowledge and behaviours of UNESCO sites' actors for disaster risk management

Knowledge and actions of UNESCO actors for disaster risk management

There are items that should be in possession of UNESCO actors, which should improve their preparations for natural disasters.

* 21. What is your level of awareness of the following items as it relates to your site?

	Not at all aware	Slightly aware	Somewhat aware	Moderately aware	Extremely aware
The attributes that carry the outstanding universal value and justify the criteria for inscription of the property on the UNESCO cultural/biosphere Heritage List	○	○	○	○	○
A list of factors and processes that will lead to damage or deterioration in the event of disaster occurrence	○	○	○	○	○
Geographical information on the location of the property, its boundaries, its buffer zone, its immediate surroundings, access, topography, and others	○	○	○	○	○
Geological information on the nature of the soil and fault lines (if any)	○	○	○	○	○
Hydrological information on the water table, surface water such as rivers and others	○	○	○	○	○
Meteorological information on the nature of the climate	○	○	○	○	○
Thematic maps of the area or region in which the property is located, such as a hazard vulnerability map	○	○	○	○	○
Information on the history of different disasters affecting the area or the property itself	○	○	○	○	○

Inventories and the status of existing management systems and disaster preparedness equipment and facilities in the property, such as for shelter, evacuation, and rescue	◯	◯	◯	◯	◯
Evaluation of hazard-specific equipment and needs e.g., the different needs for floods, fires, landslides, pollution events and disease epidemics	◯	◯	◯	◯	◯
Existing relevant institutions within the site	◯	◯	◯	◯	◯
Existing community around the site	◯	◯	◯	◯	◯
Physical planning (land use, transport and infrastructure) of the area in which the site is located	◯	◯	◯	◯	◯
Condition of roads for potential evacuation during a disaster	◯	◯	◯	◯	◯
Local and traditional knowledge systems relevant to disaster risk reduction	◯	◯	◯	◯	◯
Complete and easily accessible directory of agencies that will act during disasters	◯	◯	◯	◯	◯

* 22. Which emergency preparations are in place on your site?

	No	Yes	Not applicable
A well-developed plan and procedures for evacuating people is available	◯	◯	◯
General emergency equipment is installed	◯	◯	◯
A comprehensive strategy based on the main risks, the location of the property, and available resources and expertise is formulated	◯	◯	◯
Alarm systems, special security cordons	◯	◯	◯
Coordination between the site staff and security	◯	◯	◯
Maps of the property showing specific features such as utility mains, fire exits, fire extinguishers, and others	◯	◯	◯
Communication of the emergency plan and procedures to visitors, staff and local residents by easily readable handbooks, manuals, drawings, and signage	◯	◯	◯
Organizing awareness raising activities such as seminars and exhibitions	◯	◯	◯
Training and capacity-building on the use of emergency equipment such as fire extinguishers	◯	◯	◯
Regular emergency simulation drills in cooperation with external agencies such as fire services	◯	◯	◯

Other (please specify)

* 23. What is the estimated population of persons living within and around your UNESCO site?

* 24. What is the estimated percentage of people within and around your site who you think are prepared for disasters? *Please use the slider*

0% 100%

* 25. Which disasters are your UNESCO site prepared for? *Multiple answers are possible*

- [ ] Ground movement (Earthquake)
- [ ] Tsunami
- [ ] Rock fall
- [ ] Landslide (dry)
- [ ] Landslide (avalanche of snow, debris or mudflow)
- [ ] Volcanic activity
- [ ] Extreme cold wave
- [ ] Extreme heat wave
- [ ] Severe winter conditions
- [ ] Dense Fog
- [ ] Extra-tropical storm e.g., cyclones, blizzards
- [ ] Tropical storm e.g., hurricanes
- [ ] Convective Storm e.g., tornadoes
- [ ] Flood
- [ ] Destructive wave actions
- [ ] Drought
- [ ] Glacial Lake Outburst
- [ ] Forest Fire
- [ ] Land fire of Brush/bush/Pasture
- [ ] Violent conflicts/wars/riots/unrest/protest
- [ ] Other (please specify)
- [ ] None of the above

* 26. What disaster risk management topics are you interested in learning?

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Core competencies, knowledge and behaviours of UNESCO sites' actors for disaster risk management

Demographic information

As earlier mentioned, we intend to obtain a deeper understanding of additional factors relevant for disaster risk management based on your personal data

* 27. How old are you?

○ 18-24 years ○ 25-34 years ○ 35-44 years ○ 45-54 years ○ 55-64 years
○ 65+ years

* 28. What is your gender?

○ Male ○ Female ○ Others

* 29. What highest level of education have you completed?

○ Primary school completed ○ Secondary school qualification or equivalent
○ Polytechnic diploma ○ Trade certificate ○ Undergraduate degree
○ Postgraduate diploma ○ Master's degree ○ Doctorate

* 30. How long have you been working with the UNESCO site?

○ Less than 1 year ○ 1 to 5 years ○ 6 - 10 years ○ 11 - 15 years
○ 16 years and above

* 31. How many trainings have you attended on disaster risk management/reduction?

* 32. What are your preferred sources of Information on climate change and disasters?

33. Does your collective family income cover your household costs?

○ No, costs are considerably higher
○ No, costs are slightly higher
○ Yes, income and costs are similar
○ Yes, with a small surplus
○ Yes, comfortably

* 34. Which of these options best describe your housing situation?

- ◯ House (free standing)
- ◯ Unit/flat (joined to another unit/flat)
- ◯ Apartment in multi-level building
- ◯ Moveable dwelling (e.g., caravan, boat, tent, etc.)
- ◯ Other (please specify)

* 35. Please, indicate if you could be contacted at the next stage of this study for an interview or focus group discussion to provide me with further information and support my research

- ◯ No
- ◯ Yes. Please indicate your email address

RESEARCH GROUP FOR EARTH OBSERVATION

Organisation der Vereinten Nationen für Bildung, Wissenschaft und Kultur

UNESCO-Lehrstuhl für Erdbeobachtung und Geokommunikation von Welterbestätten und Biosphärenreservaten Pädagogische Hochschule Heidelberg

Core competencies, knowledge and behaviours of UNESCO sites' actors for disaster risk management

Completed

Thank you very much for completing this survey.

Appendix 3: Characteristics of respondents in the global survey within this study

Respondents' country

S/N	**Country**	**N**	%
1	France	10	7.41
2	España	7	5.19
3	South Africa	7	5.19
4	China	6	4.44
5	Portugal	6	4.44
6	Ukraine	6	4.44
7	Austria	4	2.96
8	Canada	4	2.96
9	Italy	4	2.96
10	Malawi	4	2.96
11	Russia	4	2.96
12	United States	4	2.96
13	Chile	3	2.22
14	Ghana	3	2.22
15	Nigeria	3	2.22
16	Paraguay	3	2.22
17	Albania & North Macedonia	2	1.48
18	ANDORRA	2	1.48
19	Bolivia	2	1.48
20	Cameroun	2	1.48
21	Comores	2	1.48
22	Costa Rica	2	1.48
23	Côte d'Ivoire	2	1.48
24	Germany	2	1.48
25	Indonesia	2	1.48
26	Luxembourg	2	1.48
27	Madagascar	2	1.48
28	Sweden	2	1.48
29	United Kingdom	2	1.48
30	USA	2	1.48
31	ANDALUCIA, ESPAÑA	1	0.74
32	Argentina	1	0.74
33	Australia	1	0.74
34	Brazil	1	0.74
35	Costa Rica - Panamá	1	0.74

36	Ecuador	1	0.74
37	El Salvador, Centroamérica	1	0.74
38	ESPAÑA-MARRUECOS	1	0.74
39	España-Portugal	1	0.74
40	Finland	1	0.74
41	Hrvatska	1	0.74
42	Hungary	1	0.74
43	Hungary and Slovakia	1	0.74
44	Japan	1	0.74
45	Latvia	1	0.74
46	Madagascar/Antananarivo	1	0.74
47	Maldives	1	0.74
48	México	1	0.74
49	Mongolia	1	0.74
50	Niger	1	0.74
51	Norway	1	0.74
52	Palau	1	0.74
53	Perú	1	0.74
54	Poland	1	0.74
55	Romania + other 11 countries	1	0.74
56	Scotland	1	0.74
57	Slovenia	1	0.74
58	Uganda	1	0.74
59	Viet Nam	1	0.74
		135	

Note:
Some respondents did not indicate their country.

Length of service

	N	%
0-5 years	25	17.7%
6-10 years	21	14.9%
11+ years	31	22.0%
Missing System	64	45.4%

What highest level of education have you completed?

	N	%
Polytechnic diploma	3	2.1%
Undergraduate degree	9	6.4%
Postgraduate diploma	10	7.1%
Master's degree	42	29.8%
Doctorate	13	9.2%
Missing System	64	45.4%

What is your gender?

	N	%
Male	42	29.8%
Female	34	24.1%
Others	1	0.7%
Missing System	64	45.4%

How old are you?

	N	%
25-34 years	11	7.8%
35-44 years	18	12.8%
45-54 years	25	17.7%
55-64 years	19	13.5%
65+ years	4	2.8%
Missing System	64	45.4%

Note:
Missing System refers to non-responses or missing data within the dataset

Emmanuel Eze *(résumé)*

ORCID: https://orcid.org/0000-0003-2007-2696

Born at: Ngala, Borno state, Nigeria | **Nationality:** Nigerian

Education

10/2021 – 10/2024	**Doctoral research [Geography]: Universität Heidelberg, Germany** • **Focus:** disaster risk management & heritage conservation in Africa • **Dissertation (working) title:** Exploring capacity gaps for improved disaster risk reduction within UNESCO-designated heritage sites in Africa
12/2016 – 04/2021	**M.Ed. [Geography and Environmental Studies]: University of Nigeria, Nsukka** • **Project title:** Capacity building needs of teachers for enhancing students' climate change awareness and adaptation in Enugu state, Nigeria. | *CGPA: 4.92/5.00*
10/2017 – 07/2019	**M.Sc. [Climate and Society]: Mekelle University, Ethiopia** • **Project title:** Drought and crop yield analyses to develop area-specific crop insurance index for the Southern Tigray, Northern Ethiopia. | *CGPA: 4.00/4.00*
12/2009 – 07/2013	**B.Sc. [Education/Geography]: University of Nigeria, Nsukka** • **Project title:** Influence of location and gender on students' achievement in West African Senior School Certificate Geography in Enugu state. | *CGPA: 4.35/5.00*

Professional experience

01/2022 – 06/2024 *(part-time)*	**Project coordinator, Sompon socialservices Baden–Württemberg e.V., Esslingen DE** • Secured over 215,000 EUR in grants from my EU project proposals • Led and coordinated staff, partners and participants collaboratively • Managed resources and quality standards for successful projects
10/2021 – 10/2024	**Doctoral researcher, Universität Heidelberg, Germany** • Designed & implemented a comprehensive mixed-methods research, with seven publications and a completed thesis • Conducted global and regional-level studies with high-impact • Stakeholder engagement, research publications/communication

08/2016 – 09/2021	**Lecturer, Geography & Environment, University of Nigeria, Nsukka** • Delivered lectures and assessments for undergraduate courses • Supervised 60+ student internships and 5+ undergraduate projects • Research, publications, curriculum development, and mentorship
09/2015 – 07/2016	**Educator, Deeper Life High School, Enugu, Nigeria** • Taught Geography, Social Studies and Security Education • Administered Basic 9 class and served as a school parent • Achieved over 80 % distinction in students grades
08/2014 – 07/2015	**Head teacher (pioneer), Tender Hearts Schools, Auchi, Nigeria** • Established, led, administered/supervised the school's activities • Conducted interviews, recruitment and training of all staff

Doctoral thesis publications

Eze, E., & Siegmund, A. (2024a). Identifying disaster risk factors and hotspots in Africa from spatiotemporal decadal analyses using INFORM data for risk reduction and sustainable development. *Sustainable Development*, 1–22. https://doi.org/10.1002/sd.2886

Eze, E., & Siegmund, A. (2024b). Analyzing important disaster risk factors for enhanced policy responses in perceived at-most-risk African countries. *Environments*, 11(2):27. https://doi.org/10.3390/environments11020027

Eze, E., & Siegmund, A. (2024c). Next-generation core competency gaps for disaster risk management and preparedness in UNESCO-designated heritage sites. *Sustainable Futures*. 8 (100239), 11, https://doi.org/10.1016/j.sftr.2024.100239

Eze, E., & Siegmund, A. (2024d). Appraising competency gaps among UNESCO-designated heritage site actors in disaster risk reduction innovations. *Progress in Disaster Science*, 22 (100321), 9. https://doi.org/10.1016/j.pdisas.2024.100321

Eze, E., & Siegmund, A. (2024e). Exploring factors of disaster preparedness in UNESCO-designated heritage sites. *Geography and Sustainability*. 5 (3), 392-404. https://doi.org/10.1016/j.geosus.2024.04.001

Eze, E., Petersen, M. & Siegmund, A. (2024). Enhancing protection motivation for disaster preparedness among actors at UNESCO-designated heritage sites in Africa. *International Journal of Disaster Risk Reduction,* 109 (104599). https://doi.org/10.1016/j.ijdrr.2024.104599

Other publications *(during the PhD)*

Obiagu, A., Ocheje, J., Ofodum, I. & **Eze, E.** (2024) Fostering environmental personal norms: the role of environmental education in Nigerian pre-service teachers' environmental knowledge, pro-environmental beliefs and behaviours. *Environmental Education Research, 30(8), 1231–1246.* https://doi.org/10.1080/13504622.2023.2297159

Eze, E., & Siegmund, A. (2023). Flash flood drivers, devastations, and directions in UNESCO biosphere reserves: Evidence from a systemic map. *International Journal of UNESCO Biosphere Reserves,* 7 (1), 23 – 37, http://dx.doi.org/10.25316/IR-19149.

Okolo, C.C., Gebresamuel, G., Zenebe, A., Haile, M., Orji, J.E., Okebalama, C.B., Eze, C., **Eze, E.,** Eze, P.N. (2023). Soil organic carbon, total nitrogen stocks and CO2 emissions in top- and subsoils with contrasting management regimes in semi-arid environments. *Scientific Reports,* 13(1), 1117. https://doi.org/10.1038/s41598-023-28276-x

Onwuzurike, U.A. & **Eze, E.** (2022). In-service and pre-service teachers' awareness and utilisation of climate change education strategies in Teaching climate change contents in University of Nigeria, Nsukka. *Nigeria Social Science Education Review,* 6(1),28-42

Kourouma, J.M., **Eze, E.,** Kelem, G., Negash, E., Phiri, D., Vinya, R., Girma, A. & Zenebe, A. (2022) Spatiotemporal climate variability and meteorological drought characterization in Ethiopia. *Geomatics, Natural Hazards, and Risk,* 3:1, 2049-2085, DOI: 10.1080/19475705.2022.2106159

Eze, E., Nwagu, E.K.N & Onuoha, J.C. (2022). Nigerian teachers' self-reported climate science literacy and expressed training needs on climate change concepts: Prospects of job-embedded situative professional development. *Science Education,* 106, 1535–1567. https://doi.org/10.1002/sce.21743

Eze, E., Girma, A., Zenebe, A., Okolo, C.C., Kourouma, J.M. & Negash, E. (2022). Predictors of drought-induced crop yield/losses in two agro-ecologies of southern Tigray, Northern Ethiopia. *Scientific Reports,* 12 (6284) https://doi.org/10.1038/s41598-022-09862-x

Fumnanya, E. & **Eze, E.** (2021). The role of social workers in developing adaptive capacities of flood-prone communities. *Journal of Social Work in Developing Societies*, 3(2), 16-28. https://journals.aphriapub.com/index.php/JSWDS/article/view/1388

Conference Presentations *(during the PhD)*

Eze, E., & Siegmund, A. (2024). Optimizing resources and competencies to enhance disaster risk reduction, resilience, and sustainability in UNESCO-designated heritage sites. *35th International Geographical Congress*, 24 – 30 August 2024, Dublin, Ireland.

Eze, E. (2023). Synergising resources for disaster risk reduction in UNESCO-designated sites towards sustainable futures. A presentation at the webinar on *"Nature Conservation and Biodiversity: Safeguarding Ecosystems for a Sustainable Future"* organised by the European Technology Chamber (EUTECH), December 8, 2023.

Eze, E., & Siegmund, A. (2023). Refocusing Africa's core policies in line with disaster risk trends in the last decade. *German Congress for Geography (DKG) 2023*, September 19 – 23, 2023, Goethe-Universität Frankfurt am Main, Germany.

Eze, E., & Siegmund, A. (2023). Disaster risk factors and spatiotemporal trends in Africa. *EGU General Assembly 2023,* Vienna, Austria, 24–28 Apr 2023, EGU23-8307,

Eze, E. (2023). Addressing the causes of students' poor achievement in geography examinations to reverse enrollment decline. Asso*ciation of Nigerian Geographers 62nd Annual National Conference,* February 7 – 11 2023, University of Nigeria, Nsukka.

Eze, E., & Siegmund, A. (2022). Responsiveness of national action plans to disaster risk predictors in Africa. *American Geophysical Union (AGU) Fall Meeting 2022,* December 12–16, 2022. Chicago, IL, USA.

Eze, E., & Siegmund, A. (2022). What evidence exists on the drivers, devastations and directions of flash floods in biosphere reserves? *Flood Knowledge Summit* at UNU-MERIT, Maastricht, the Netherlands on July 7 – 8, 2022.

Journal peer review activities (selected)

1. Agriculture
2. Applied Sciences
3. Agricultural Water Management
4. Agronomy
5. Applied Environmental Education and Communication
6. Atmosphere
7. Climate Risk Management
8. Earth's Future
9. Earth and Space Science
10. European Journal of Geography
11. History in Africa
12. International Journal of Agricultural Sustainability
13. International Journal of Climatology
14. International Journal of Disaster Risk Reduction
15. International Journal of Environmental & Science Education
16. Journal of Geography
17. Natural Hazards Research
18. Science Education
19. Sustainable Futures
20. Sustainability
21. UNESCO Climate Change Communication and Education Profile,

etc.

Professional development activities (selected)

- Grant writing, Euraxess, 2023
- Open Access and Open Science, Universität Heidelberg, 2022
- Research & Peer review, Elsevier Research Academy, 2022
- Research Data Science, CODATA-ICTP, 2022
- Research Integrity & Ethics, Epigeum, 2022
- Risk and crisis communication, Coimbra, 2024
- Science journalism, Marsilius Kolleg, 2023
- Small-Scale Partnerships for Inclusion, Erasmus+, 2023
- Visual science communication, Seyens, Esri, 2022

Teaching/facilitation experience

- Sompon Socialservices BW e.V.: Co-facilitator – Erasmus youth projects, 2022 – *present*
- Pädagogische Hochschule Heidelberg: Co–facilitator: Mensch-Umwelt Systeme Course, 2023
- University of Nigeria: Co-lecturer, ED204: Environmental Education (UG)
- University of Nigeria: Co-lecturer, ED222: Special methods in Geography (UG)
- University of Nigeria: Co-lecturer, SS301: Study of Events in Places (UG)
- University of Nigeria: Co-lecturer, SS401: Study of Ideas in Space (UG)
- University of Nigeria: Co-lecturer, ED325 and ED425: Teaching Practice (UG)

Skills

Research

- Academic writing
- Editorial and peer review
- Grant writing and project management
- Leadership, supervision & mentorship
- Qualitative, Quantitative & Mixed methods
- Scientific publications and communication
- Stakeholder engagement

Digital

- ArcGIS Pro – *intermediate*
- Data analysis: SPSS, R, MAXQDA, & Excel
- Microsoft office suite – *advanced*
- Scopus & Web of Knowledge databases
- Video editing: Davinci, &Clipchamp
- Visualization: R, Canva, Corel & PowerPoint + YouTube
- Zoom, MS Teams & Google meet

Awards

Scholarships

- Doctoral research grant, 2021 – 2025: Deutscher Akademischer Austauschdienst (DAAD),
- Full Master Mobility, 2017 – 2019: EU funded TRECCAfrica Intra-ACP Scholarship Award
- University Scholarship Award 2009 – 2013: Shell Petroleum Development Company, Nigeria

Grants

- Travel, 2024: Young Researcher's Fund, Graduate Academy, Universität Heidelberg (€700)
- Travel, 2024: International Geographical Union (IGU) ($500)
- Travel, 2022: European Geosciences Union (EGU) (€600)
- Certificate of Merit, 2013: Departmental Best Graduating Student, University of Nigeria, Nsukka

Professional memberships (selected)

- Academic Staff Union of Universities (ASUU), Nigeria
- African Students and Alumni Forum (ASAF)
- American Geophysical Union (AGU)
- Association of Nigerian Geographers (ANG)
- European Geosciences Union (EGU)
- Natural Hazards/Risks Working Group of German Society for Geography (DGfG)
- Nigerian Institute of Management (NIM) (Chartered)
- Teachers Registration Council of Nigeria (TRCN)

NATURWISSENSCHAFTLICH-MATHEMATISCHE
GESAMTFAKULTÄT

COMBINED FACULTY OF NATURAL SCIENCES AND MATHEMATICS

RUPRECHT-KARLS-
UNIVERSITÄT
HEIDELBERG

Eidesstattliche Versicherung gemäß § 8 der Promotionsordnung für die Naturwissenschaftlich-Mathematische Gesamtfakultät der Universität Heidelberg / Sworn Affidavit according to § 8 of the doctoral degree regulations of the Combined Faculty of Natural Sciences and Mathematics

1. Bei der eingereichten Dissertation zu dem Thema / The thesis I have submitted entitled

   Exploring capacity gaps for improved disaster risk reduction within UNESCO-designated heritage sites in Africa

   handelt es sich um meine eigenständig erbrachte Leistung / is my own work.

2. Ich habe nur die angegebenen Quellen und Hilfsmittel benutzt und mich keiner unzulässigen Hilfe Dritter bedient. Insbesondere habe ich wörtlich oder sinngemäß aus anderen Werken übernommene Inhalte als solche kenntlich gemacht. / I have only used the sources indicated and have not made unauthorised use of services of a third party. Where the work of others has been quoted or reproduced, the source is always given.

3. Die Arbeit oder Teile davon habe ich wie folgt/bislang nicht[1] an einer Hochschule des In- oder Auslands als Bestandteil einer Prüfungs- oder Qualifikationsleistung vorgelegt. / I have not yet/have already[1] presented this thesis or parts thereof to a university as part of an examination or degree.

   Titel der Arbeit / Title of the thesis: None

   Hochschule und Jahr / University and year: None

   Art der Prüfungs- oder Qualifikationsleistung / Type of examination or degree: None

4. Die Richtigkeit der vorstehenden Erklärungen bestätige ich. / I confirm that the declarations made above are correct.

5. Die Bedeutung der eidesstattlichen Versicherung und die strafrechtlichen Folgen einer unrichtigen oder unvollständigen eidesstattlichen Versicherung sind mir bekannt. / I am aware of the importance of a sworn affidavit and the criminal prosecution in case of a false or incomplete affidavit

Ich versichere an Eides statt, dass ich nach bestem Wissen die reine Wahrheit erklärt und nichts verschwiegen habe. / I affirm that the above is the absolute truth to the best of my knowledge and that I have not concealed anything.

29.07.2024
Ort und Datum / Place and date

………………………………………………………………
Unterschrift / Signature

[1] Nicht Zutreffendes streichen. Bei Bejahung sind anzugeben: der Titel der andernorts vorgelegten Arbeit, die Hochschule, das Jahr der Vorlage und die Art der Prüfungs- oder Qualifikationsleistung. / Please cross out what is not applicable. If applicable, please provide: the title of the thesis that was presented elsewhere, the name of the university, the year of presentation and the type of examination or degree.

The German text is legally binding.

Instruction concerning the

Sworn Affidavit

The German text is legally binding.

The universities in the state of Baden-Württemberg request a sworn affidavit concerning the sole authorship of the scientific achievements, in assurance that the doctoral student's work is his or her own individual research.

The legal system associates a particular meaning and serious consequences with a sworn affidavit, and thus penalizes false sworn affidavits. Intentional (consciously made) false affidavits can be punished with up to 3 years of imprisonment or a fine.

A negligent offence (an affidavit made in spite of the fact that you should have noticed that the declaration is not true) can result in imprisonment for up to one year or a fine.

The corresponding penal provisions to be found in § 156 StGB (German Criminal Code) for false sworn affidavits and § 161 StGB for negligent offences.

§ 156 StGB: False sworn affidavits

Whosoever before a public authority competent to administer sworn affidavits, falsely makes such an affidavit or falsely testifies while referring to such an affidavit shall be liable to imprisonment of not more than three years or a fine.

§ 161 StGB: Negligent offences

(1) If a person commits one of the offences listed in §§ 154 to 156 negligently the penalty shall be imprisonment of not more than one year or a fine.

(2) The offender shall be exempt from liability if he corrects his false testimony in time. The provisions of § 158 (2) and (3) shall apply accordingly.

Acknowledged on 29.07.2024 ____________________ ____________________

Date Signature

03/2019