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Flash flood drivers, devastations, and directions in UNESCO Biosphere Reserves: Evidence from a systematic map

Emmanuel Eze[1,2,3*] and Alexander Siegmund[1,2]

[1] Institute of Geography & Heidelberg Center for the Environment (HCE), University of Heidelberg, Heidelberg, Germany.
[2] Department of Geography - Research Group for Earth Observation (ʳgeo), UNESCO Chair on Observation and Education of World Heritage & Biosphere Reserve, Heidelberg University of Education, Heidelberg, Germany.
[3] Geographical and Environmental Education Unit, Department of Social Science Education, University of Nigeria, Nsukka, Nigeria.

* Correspondence: emmanuel.eze@stud.uni-heidelberg.de

Abstract

Background

Flash floods are devastating because of their abruptness. Moreover, scientists expect increased flash flood frequency from current precipitation extremes due to climate change. Such recurrence of flash floods has implications for biosphere reserves, which house varieties of plants, animals and micro-organisms and support residents' livelihoods.

Aims/objectives

Synthesised evidence of flash floods' causes, consequences and management within biosphere reserves is absent, hence this study. The primary question of this research is, what evidence exists on the drivers, devastations and directions of flash floods in biosphere reserves? Four other sub-questions ensue about flash floods in UNESCO Biosphere Reserves, which guide this study.

Methods

The Web of Science Core Collection (WoS) served as the primary data source for this study. In addition, separate searches of Google Scholar and one journal's database were conducted to identify literature not captured by the WoS search. Finally, two article screening stages were done: title/abstract and full-text screening. The pre-set criteria for including articles in the study was that such articles report flash flooding in a biosphere reserve.

Findings

The search in WoS, Google Scholar and the International Journal of UNESCO Biosphere Reserves database returned 226, 382 and zero articles, respectively. A total of 12 papers have been included in the study following the pre-set criteria and guiding questions. Lastly, coding and narrative synthesis of the papers were implemented to extract findings. There is evidence of both natural and anthropogenic drivers of flooding, its influence on the natural and built environments within the biosphere reserve, and commonly adopted management techniques.

Keywords

climate change;
flash flood;
systematic map;
UNESCO biosphere reserve

Highlights:

- Varied views exist on climate's role in flash flood occurrence in biosphere reserves.
- Flash floods primarily cause infrastructural damage and loss of human lives in biosphere reserves.
- Needs for monitoring, assessment, community sensitisation and integration of innovation emerge.

1. Introduction

Biosphere reserves are unique landscapes globally recognised by the United Nations Educational Scientific and Cultural Organization (UNESCO) to include a compatible blend of nature's conservation, cultural diversity and economic development. Acknowledged as sustainability models, biosphere reserves are composed of a transitional zone, a core area, and a buffer zone, with low, lesser, and no human interference, respectively. They also serve as sustainability laboratories for scientists (Pavlova et al., 2022).

Flash floods are devastating because of their abruptness. The United Nations Office for Disaster Risk Reduction [UNDRR] (2020) pegs flash flooding at 44 % of reported disasters, affecting over 1.6 billion people worldwide. Natural and anthropogenic factors could drive them. Furthermore, scientists expect flash floods to occur more frequently with the current precipitation extremes due to climate change (Meyer et al., 2021). Such recurrence of flash floods has implications for biosphere reserves, which house varieties of plants, animals and micro-organisms and support residents' livelihoods.

Some systematic reviews have been conducted on flood research. For example, Kassim and Daniell (2021) synthesised papers to relate flood management with flood resilience, while Wagner et al. (2021) examined flood risk management in West Africa. Moreover, the systematic review of Alrehaili (2021) focused on emergency planning for flash flood response in Saudi Arabia. Whereas the study of Rehman et al. (2019) considered the approaches and methods used for flood vulnerability assessment, Moreira et al. (2021) assessed the methods used in constructing flood vulnerability indices and provided helpful guidance for subsequent studies. Other studies, such as Venkataramanan et al. (2019) and Friederike and Steinert (2021), considered floods' health and social outcomes. None of these studies has situated the reviews to the unique terrain of the 727 biosphere reserves globally, hence this study.

This paper synthesises relevant research on this topic by mapping the existing evidence on flash floods in biosphere reserves. It enables a clearer picture of critical areas of interest for further investigation. The results encompass research on flash floods from all biosphere reserves, allowing the Man and the Biosphere (MAB) Programme of UNESCO to utilise knowledge gained from different contexts around the globe.

1.1. Aims/objectives

Synthesised evidence of flash floods' occurrence, consequences and management within biosphere reserves is absent. Therefore, this systematic map's primary objective is to identify, collate and categorise what drives flash floods, what devastations they cause and how they are managed in biosphere reserves. Thus, this study demonstrates global literature trends and identifies knowledge gaps that researchers could improve.

1.2. Primary question and its definition

The primary question of this research is, what evidence exists on the drivers, devastations, and directions of flash floods in biosphere reserves? Other sub-questions thus ensue about UNESCO Biosphere Reserves: (i) What drives flash floods? (ii) what devastations are caused by flash floods? (iii) what are the direction or management strategies employed before, during and after flash floods? Finally, (iv) what knowledge gaps exist in flash flood research on biosphere reserves?

For simplicity of presentation, the research objective and primary question are decomposed using the 'Population'- 'Exposure' - 'Outcome' (P-E-O) structure. 'Population' includes all the 727 UNESCO biosphere reserves globally, 'Exposure' refers to flash flood events, and 'Outcome' represents flood drivers, devastations, and directions (management) captured.

2. Materials and Methods

This systematic mapping review conforms to the ROSES (RepOrting standards for Systematic Evidence Syntheses) of Haddaway et al. (2018).

2.1. Search strategy

2.1.1. Bibliographic databases

The literature search for this systematic mapping review was undertaken using the Web of Science Core Collection database. The University of Heidelberg provides access to the database (https://dbis.ur.de/dbinfo/detail.php?bib_id=ubhe&colors=&ocolors=&lett=fs&tid=0&titel_id=2142). The literature search was conducted in English on the "Topic" (TS) field to include article titles, abstracts, keywords, and Keywords Plus. All years of data are included. In addition, search results were exported in BibTeX format.

2.1.2. Supplementary searches

In addition to the Web of Science Core Collection search, separate searches of one web-based search engine (Google Scholar: https://scholar.google.com/) and one journal database (The International Journal of UNESCO Biosphere Reserves: https://biospherejournal.org/database/) were conducted to identify literature not captured by the primary bibliographic database search.

2.1.3. Search string

The search strings and links for the database searches are presented in Table 1.

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Table 1
Search strings and query links for database search

Data-base	Search string	Query links
WoS	(ALL=(biosphere reserve)) AND ALL=(flood*)	https://www.webofscience.com/wos/woscc/summary/1e0228f8-1926-4df8-9327-44929a5684c7-3c9f83e2/relevance/1
GSch	"flash flood" AND "biosphere reserve"	https://scholar.google.com/scholar?start=0&q=%22flash+flood%22+AND+%22biosphere+reserve%22&hl=en&as_sdt=0,5
IJBRD	"flood"	https://biospherejournal.org/database/

Notes: WoS = Web of Science; GSch = Google Scholar; IJBR = The International Journal of UNESCO Biosphere Reserves Database

2.2. Eligibility criteria for selected articles

2.2.1. Inclusion criteria following the P-E-O structure

- Population: only articles conducted in biosphere reserves are included in our systematic map.
- Exposure: studies to be included in our systematic maps focus on flash flooding. Hence, this systematic map excludes articles considering other forms of floods, such as coastal flooding or flood plains.
- Outcome: only studies that capture any or all of the sub-questions (i.e., the drivers, devastations and directions (management) of flash floods within the specified population are included.

2.2.2. Article screening

The BibTeX file generated from the Web of Science core collection search downloaded from the search string provided in Table 1 is loaded in 'revtools'. Revtools is an 'R' package developed by Westgate (2019) and has been used for deduplication and conducting title and abstract screening of downloaded articles for synthesis in this study. Papers are assessed based on the eligibility criteria presented in the earlier section. The record of included/excluded articles and reasons are compiled and showcased (Fig. 1).

2.3. Data coding

Descriptive analyses of included articles in this systematic mapping study present basic information such as the studied biosphere reserve, year of flooding, study type, and data type (Table 2). Next, thematic categories of crucial findings from included articles are created using the Citavi web. Finally, two steps are followed for coding results from the selected papers, namely the line-by-line reading of the full texts and assigning relevant portions of the papers to pre-assigned Citavi knowledge items corresponding to the sub-questions of this systematic map.

3. Results

3.1. Meta-information of included studies

This systematic map includes 12 records from the 608 identified articles from our database and web searches. In addition, the ROSES flowchart of Haddaway et al. (2017) depicts the screening process followed in this study (Figure 1). The included studies were carried out in Austria (*n* = 1), China (*n* = 1), Ecuador (*n* = 1), Germany (*n* = 1), India (*n* = 6) and Indonesia (*n* = 1). Also, 50 % of the studies were conducted in India, with 83.33 % of the included articles being case studies (Table 2).

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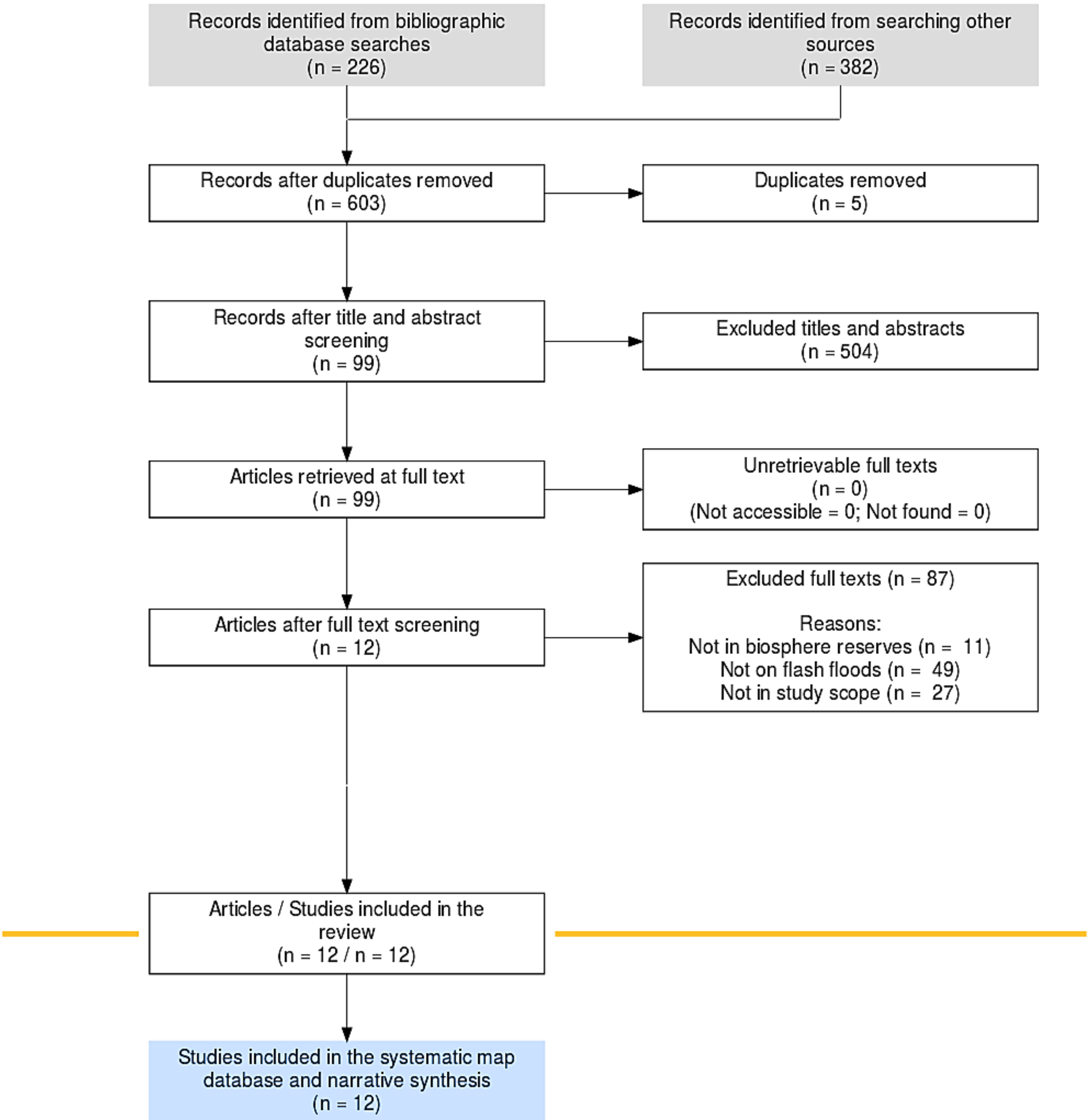

Figure 1: ROSES flowchart of the screening process.
Source: Authors' data

Table 2
Summary of included studies

Study	Biosphere Reserve (BR)	Year of flooding	Study type	Data type	Study participants/sample size
Aksa and Sinulingga (2022)	Gunung Leuser National Park (GLNP), Indonesia	2020	Cross-sectional survey design	Survey responses on disaster experience, risk perception, and flood disaster preparedness	208 respondents
Nyberg (2006)	Elbe River landscape, Germany	2002	Case study description		Case study

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Dandabathula, et al. (2021)	Nanda Devi BR, India	2021	Case study report	Geospatial data (e.g., multi-sensor satellite data, open-source Digital Elevation Models (DEM), space-borne Laser Altimeter and reanalysed weather data)	Case study
Mehta, et al. (2021)	Nanda Devi BR, India	2021	Case study report	Gridded climate data and field survey	Case study
Muñoz, et al. (2018)	Cajas National Park, Ecuador	Not applicable	Case study (Flash-flood forecasting with machine learning)	Data comprises precipitation and runoff hourly time series for a period of 2.5 years discharge time series	Case study
Rana, et al. (2021)	Nanda Devi BR, India	2021	Case study report	Remote sensing data, Flood inundation measurements; Digital Elevation Model; Photographs; Field observations	Case study
Sain, et al. (2021)	Nanda Devi BR, India	2021	Case study report	Google Earth imagery, ground-based and heliborne survey	Case study
Sati, (2022).	Nanda Devi BR, India	2021	Case study report	Agency reports, field observation and interviews	Case study
Taloor et al. (2022)	Nanda Devi BR, India	2021	Case study report	Remotely-sensed images	Case study
Thaler, et al. (2021)	Not specified	Not specified	Transdisciplinary research	Stakeholders interactions	Not specified
Tuniyev & Beregovaya (1993)	Caucasian State BR, Russia	Not specified	Field observations along transect routes	location, weather conditions, air and body temperature, and behavior of selected species; water sample; Ambient light; Feeding habits	Case study
Wang, et al. (2021)	The Jiuzhaigou National Nature Reserve, China	2017	Field investigation and numerical simulation	Remotely sensed images	Case study

3.2. Drivers of flood in biosphere reserves

Flash floods in biosphere reserves captured in this systematic map have diverse drivers (Figure 2). Various anthropogenic activities are reported as recurring drivers of flash floods, as almost half of the included studies (i.e., 41.67 %) describe. For example, Nyberg et al. (2006) identify the exposure of infrastructure developed in flood-prone areas and former river courses. Similarly, Taloor et al. (2022) mention that road and hydropower construction preceded flash flood disasters.

In addition, Sati (2022) connects the warming of the studied catchment to activities such as the construction of hydroelectricity power projects, quarrying and mining. He indicates that people constructed settlements along the banks of two rivers. Likewise, the establishment of over 300 homes and hotels along the Bahorok River and the massive deforestation of about 30,000 hectares of land in the last decade, according to Aksa and Sinulingga (2022), have worsened flash flood risks. For Mehta et al. (2021), the flash flood disaster was due to increased human developmental activities, which they did not mention. However, they did indicate that human construction structures now obstruct rivers' natural paths.

Furthermore, this study captures the evidence of other drivers of flash floods in biosphere reserves. Specifically, this study identifies natural factors, technical preparations, increased rainfall intensity and cascading disasters as non-anthropogenic drivers of flash floods in biosphere reserves. Topography, geologic and tectonic factors are natural factors that drive flash floods in biosphere reserves (Sain et al., 2021; Taloor et al., 2022).

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For instance, drainage areas of mountainous river basins will quickly experience flash floods during heavy rainfall (Aksa and Sinulingga 2022).

Also, Dandabathula et al. (2021) report accelerated flow downstream due to slope. Furthermore, according to Nyberg et al. (2006), such floods will have a very high velocity. Also, slope favoured cascading disasters such as rolling detached rocks across glacial cliffs, which led to flash floods (Taloor et al., 2022).

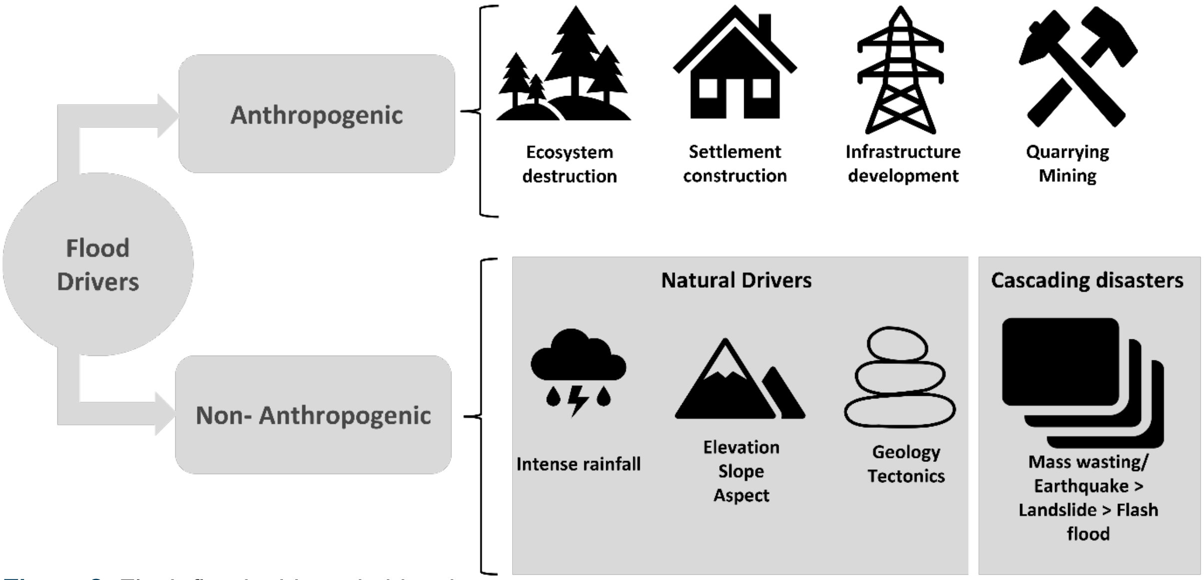

Figure 2: Flash floods drivers in biosphere reserves
Source: Authors' systematic review

Therefore, flash floods also occur in biosphere reserves due to cascading disasters. Landslides frequently precede flash floods. Aksa and Sinulingga (2022) report a high landslide hazard index for their study area. Dandabathula et al. (2021) show the case of a landslide, which generated heat energy leading to a flood-filled moraine hastening downstream. Mass wasting, avalanche and earthquakes sometimes trigger such landslides (Mehta et al., 2021; Rana et al., 2021; Sain et al., 2021; Sati, 2022; Taloor et al., 2022; Wang et al., 2021).

Climate is also a driver of flash floods in biosphere reserves. Whereas Mehta et al. (2021) explicitly blame global warming for the breaking and detachment of hanging glaciers, Taloor et al. (2022) conclude that the combination of climatic and geological factors led to flash floods in their study area. Conversely, Sain et al. (2021) deemed it premature to link flash floods to climate change.

3.3. Devastations of flood in biosphere reserves

This systematic map identified several devastations in biosphere reserves by flash floods (Figure 3). The most reported impact of flash floods in the included studies is infrastructural damages (66.67 %), followed closely by loss of human lives (58.33 %). Past flash floods destroyed transportation infrastructures such as roads, footpaths, train stations, railways, and bridges (Nyberg et al., 2006; Mehta et al., 2021; Sain et al., 2021). In addition to the destruction of road networks, Wang et al. (2021) record the ravaging of tourism infrastructure.

Two major hydroelectric projects with a joint capacity of ~534 megawatts were also wrecked by flash floods (Dandabathula et al., 2021; Mehta et al., 2021; Rana et al., 2021; Sain et al., 2021; Taloor et al., 2022). Sati (2022) presents these hydroelectric projects as both drivers and devastations of flash floods. Thousands of houses were damaged by flash floods too. The destruction of houses led to human displacement and forced migration (Wang et al., 2021; Aksa & Sinulingga 2022).

Human lives were lost to past flash floods. The authors of the included studies utilised different wording in their reports. Some studies, such as Dandabathula et al. (2021), Wang et al. (2021) and Sati (2022), used terms such as human loss, few fatalities, and human casualties, respectively. Other included studies specified the number of lives lost. Over 200 people were reported missing, swept away or trapped in tunnels within the Nanda Devi Biosphere Reserve, India, due to the 2021 flash floods (Mehta et al., 2021; Rana et al., 2021; Taloor et al., 2022). Livestock was also affected (Mehta et al., 2021). According to the report of Nyberg (2006), 38 people died from flash floods within the Elbe River landscape in Germany.

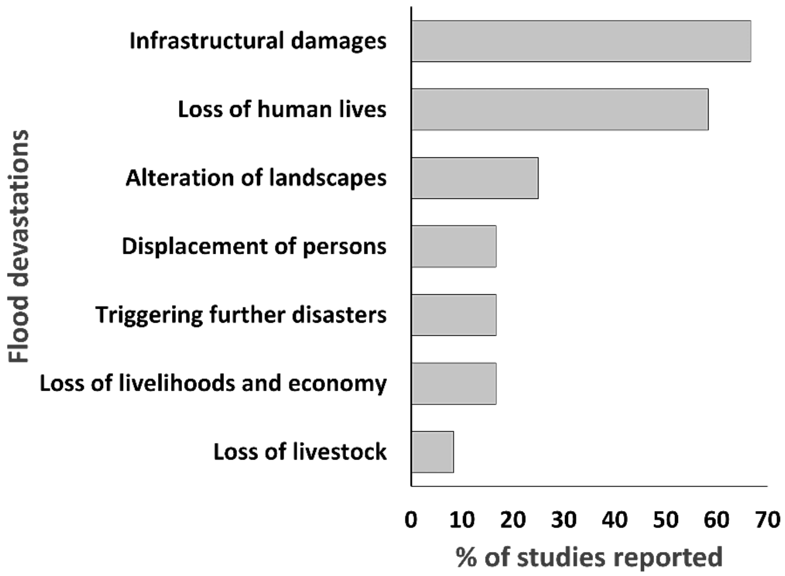

Figure 3: Flash floods devastations in biosphere reserves
Source: Authors' systematic review

The study of Aksa and Sinulingga (2022) assessed the 2020 Flood in the Gunung Leuser National Park (GLNP), Indonesia, and reported the loss of an unspecified number of human lives. However, they indicate 300 deaths, six deaths, and one in earlier floods of 2003, 2006 and 2014, respectively. Livelihoods were also affected by flash floods. Sati (2022) alluded to the loss of the economy, while Nyberg et al. (2006) reported that flash floods incurred economic damage of 11.6 billion Euros.

Flash floods reportedly altered natural landscapes and aquatic ecosystems. Although Mehta et al. (2021) captured the landscape changes in the Rishiganga and Dhauliganga valleys due to flash floods, they gave no detailed description of these changes. On the other hand, Wang et al. (2021) specified that floods significantly damaged the protected vegetation. Tuniyev and Beregovaya (1993) study recorded an increase in the concentration of Ammonium, Nitrites and Nitrogen in the aquatic environment due to flash floods. In addition to these increased chemical elements and compounds inhibiting aquatic life, flash floods destroy the eggs of studied toads (Tuniyev & Beregovaya, 1993).

Finally, flash floods contribute to cascading disasters. For example, flash floods triggered several landslides in the Jiuzhaigou National Nature Reserve, China (Wang et al., 2021). Similarly, flash floods increased the fragility and vulnerability of the Nanda Devi Biosphere Reserve, India, to landslides and debris flow (Mehta et al., 2021).

3.4. Directions/management of flood in biosphere reserves

This systematic map presents several flood disaster management techniques in the studied areas. The status of directions for flood management provided in the included studies was either before or after the disaster. Before the flood disaster, the Gunung Leuser National Park (GLNP) community was poorly prepared and unsupported by the government to build capacity. Flood risk perception and previous experiences with disasters affected individuals' preparedness (Aksa & Sinulingga 2022). In the case of the community at Nanda Devi Biosphere Reserve, India, platforms for prompt information dissemination were unavailable (Sati, 2022).

After a flood disaster, Dandabathula et al. (2021) adopted an integration of optical remote sensing and digital elevation models to assess the spatial constituents of a flood disaster at the landscape level. They recommend similar tools for undertaking disaster assessments in similar rugged topographies. Research efforts and inquiries must be collaboratively implemented to incorporate all relevant stakeholders across disciplines (Sati, 2022; Thaler et al., 2021).

Several crucial recommendations are presented by the studies included in this systematic map for managing flood disasters in biosphere reserves. Researchers have a role in providing relevant direction for flood risk management in biosphere reserves. Before disasters, glaciers should be monitored for developing early warning systems while surrounding communities ought to be sensitised for flood risk reduction (Sain, et al., 2021; Sati, 2022; Taloor et al., 2022).

Moreover, the need to conduct vulnerability assessments on susceptible areas is emphasised by Sati (2022); and Taloor et al. (2022). Also, researchers and practitioners should include debris flow and flash floods of rivers in hazard assessments, as well as assess geodiversity in the context of climate change to predict future

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floods (Rana et al., 2021; Taloor et al., 2022). Muñoz et al. (2018) advocate using machine learning techniques for flash-flood forecasting and hazard assessment.

Finally, governments have crucial responsibilities before and after flood disasters. Before disasters occur, the government should arrest increased development and urbanisation activities in rebuilding devastated areas (Mehta et al., 2021). Furthermore, environmental, and social impact analyses (E/SIA) should precede construction projects to determine safe areas (Sati, 2022). Policies should incorporate nature-based solutions such as large-scale afforestation, which are required in such fragile landscapes as biosphere reserves (Sati, 2022). Flood risk management sometimes excludes floodplain revitalisation and natural vegetation development, which follow ecological perspectives (Nyberg et al., 2006). Funding is also captured as the government's input to reparation and preparation for flood disasters. For example, after the 2002 flood, the German government established a national fund of around 10 billion Euros for infrastructure reparation and dike construction for flood protection (Nyberg et al., 2006).

3.5. Additional findings on the frequency of flooding

From the included studies, an additional result ensues. Some of the papers included the frequency of flash floods in the studied biosphere reserve. For example, Nyberg (2006) indicates that the Elbe River landscape in Germany witnessed flash floods in 1981, 1988, 2002, 2003, and 2006. Similarly, Aksa and Sinulingga (2022) listed previous flash floods in 2003, 2006, 2013, 2014, 2015, and 2020 within the Gunung Leuser National Park (GLNP), Indonesia. However, for the Nanda Devi Biosphere Reserve, India, only 2013 and 2021 are mentioned.

3.6. Limitations of the review

A limitation of this map is that it only included English-language articles. Some papers could have been missed based on their publications in languages other than English. The scarcity of available studies on flash floods in UNESCO biosphere reserves globally limits the depth, scope, and comprehensiveness of understanding this critical issue, posing challenges to effective risk assessment, management, and policy formulation in these sensitive areas.

4.0. Conclusion

This systematic map sought to synthesise the literature evidence available on flash floods in UNESCO-designated biosphere reserves. Flash floods in biosphere reserves occur from three significant causes – natural characteristics of the site, anthropogenic activities, and cascading disasters. Anthropogenic activities such as road, settlement, hydropower construction, quarrying and mining are reported as recurring drivers of flash floods. In addition, topography, geologic and tectonic factors are natural factors triggering flash floods in biosphere reserves.

There is a divergent view of the role of climate in the occurrence of flash floods in biosphere reserves. Generally, flash floods destroyed human and animal lives, livelihoods and infrastructure. Also, displacement of persons, alteration of the biosphere reserves' landscape and other disasters followed some flood events. Residents, researchers, and governments have roles in managing risks before a flood event.

This study revealed that researchers had understudied flash floods in biosphere reserves. Specifically, no study was found reporting the incidence of flash floods in Africa. Much work on flood assessments for risk management is required in Africa. Lumbroso (2020) acknowledges that floods have overtaken droughts based on the number of people affected while decrying the general lack of peer-reviewed journal papers and specific research on flood risk management in Africa.

Implications for policy/management

The evidence obtained in this map depicts that community preparation is necessary before flash flood events. Natural factors of these events (e.g., climate, topography, geologic and tectonics) are mostly constant. Therefore, it behoves the residents in these areas to be prepared. Furthermore, platforms for information dissemination from warning systems are required. A synergy is thus expected between the local management of the biosphere reserves and the government to achieve flood disaster preparedness.

Government support is required in sensitising the populace, especially those who have not witnessed flood events. In addition, the government must check unsustainable developmental activities in areas surrounding biosphere reserves and implement policies that favour nature-based solutions.

Implications for research

Identified evidence in this paper should shape future flood research in biosphere reserves globally. Integration of contemporary technologies, such as optical remote sensing, digital elevation models and unmanned aerial vehicles, is expected in assessing and monitoring rugged topographies. Moreover, collaborative, and

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transdisciplinary research is highly encouraged to develop effective early warning systems to reduce the number of affected persons during a flash flood.

Declarations

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Data Availability Statement: The literature incorporated within the systematic map is appropriately cited and accessible.

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Conflicts interests: The authors declare that they have no competing interests.

Compliance with Ethical Standards: This research does not involve human participants and/or animals. Ethical clearance was not required for this study.

CRediT authorship contribution statement

Emmanuel Eze: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization. **Alexander Siegmund:** Writing - review & editing, Supervision.

References

Aksa, F. I., & Sinulingga, E. (2022). Risk Perception and Preparedness in Flash Flood-Affected Communities: Evidence from Bahorok, Indonesia. *Geosfera Indonesia*, 7(1), 61. https://doi.org/10.19184/geosi.v7i1.28645

Alrehaili, N. R. (2021). A systematic review of the emergency planning for flash floods response in the kingdom of Saudi Arabia. *The Australian Journal of Emergency Management*, 36(4), 82-88. http://www.doi.org/10.47389/36.4.82

Birkmann, J. (2006). *Measuring vulnerability to natural hazards: Towards disaster resilient societies*. United Nations University.

Dandabathula, G., Sitiraju, S. R., & Jha, C. S. (2021). Investigating the 7th February, 2021 Landslide Triggered Flash Flood in the Himalayan Region Using Geospatial Techniques. *European Journal of Environment and Earth Sciences*, 2(4), 75-86. https://doi.org/10.24018/ejgeo.2021.2.4.170

Haddaway, N. R., Macura, B., Whaley, P., & Pullin, A. S. (2018). ROSES RepOrting standards for Systematic Evidence Syntheses: pro forma, flow-diagram and descriptive summary of the plan and conduct of environmental systematic reviews and systematic maps. *Environmental Evidence*, 7(1), 1-8. https://doi.org/10.1186/s13750-018-0121-7

Haddaway, N.R., Macura, B., Whaley, P., & Pullin, A.S. (2017). *ROSES flow diagram for systematic maps*. Version 1.0. DOI: 10.6084/m9.figshare.6085940

Kassim, A., & Daniell, K. (2021). Flood risk management governance and resilience: A systematic literature review. *E-proceeding 8th international conference on public policy and social science (ICoPS)*. https://ir.uitm.edu.my/id/eprint/54439/1/54439.pdf. Accessed 16/6/2022

Lumbroso, D. (2020). Flood risk management in Africa. *Journal of Flood Risk Management*, 13(3). https://doi.org/10.1111/jfr3.12612

Mehta, M., Kumar, V., Sain, K., Tiwari, S. K., Kumar, A., & Verma, A. (2021). Causes and Consequences of Rishiganga Flash Flood, Nanda Devi Biosphere Reserve, Central Himalaya, India. *Current Science*, 121(11), 1483. https://doi.org/10.18520/cs/v121/i11/1483-1487

Meyer, J., Neuper, M., Mathias, L., Zehe, E., & Pfister, L. (2021). More frequent flash flood events and extreme precipitation favouring atmospheric conditions in temperate regions of Europe. *Hydrology and Earth System Sciences Discussions*, 1-28. [preprint], https://doi.org/10.5194/hess-2021-628, in review.

Moreira, L. L., de Brito, M. M., & Kobiyama, M. (2021). A systematic review and future prospects of flood vulnerability indices. *Natural Hazards and Earth System Sciences*, 21(5), 1513-1530. https://doi.org/10.5194/nhess-21-1513-2021

Muñoz, P., Orellana-Alvear, J., Willems, P., & Célleri, R. (2018). Flash-Flood Forecasting in an Andean Mountain Catchment–Development of a Step-Wise Methodology Based on the Random Forest Algorithm. *Water*, 10(11), 1519. https://doi.org/10.3390/w10111519

Pavlova, I., Amirzada, Z., Pulvirenti, B., Ruggieri, P., Leo, L. S., Kalas, M., and Di Sabatino, S. (2022). European Biosphere Reserves - open air laboratories for tackling hydrometeorological hazards, OPERANDUM project. *EGU General Assembly 2022*, Vienna, Austria, 23-27 May 2022, EGU22-10141, https://doi.org/10.5194/egusphere-egu22-10141.

Rana, N., Sundriyal, Y., Sharma, S., Khan, F., Kaushik, S., Chand, P., Bagri, D. S., Sati, S. P., & Juyal, N. (2021). Hydrological Characteristics of 7th February 2021 Rishi Ganga Flood: Implication towards Understanding Flood Hazards in Higher Himalaya. *Journal of the Geological Society of India*, 97(8), 827-835. https://doi.org/10.1007/s12594-021-1781-4

Rehman, S., Sahana, M., Hong, H., Sajjad, H., & Ahmed, B. B. (2019). A systematic review on approaches and methods used for flood vulnerability assessment: framework for future research. *Natural Hazards*, 96(2), 975-998. https://doi.org/10.1007/s11069-018-03567-z

Sain, K., Kumar, A., Mehta, M., Verma, A., Tiwari, S. K., Garg, P. K., Kumar, V., Rai, S. K., Srivastava, P., & Sen, K. (2021). A Perspective on Rishiganga-Dhauliganga Flash Flood in the Nanda Devi Biosphere Reserve, Garhwal Himalaya, India. *Journal of the Geological Society of India*, 97(4), 335-338. https://doi.org/10.1007/s12594-021-1691-5

Sati, V. P. (2022). Glacier bursts-triggered debris flow and flash flood in Rishi and Dhauli Ganga valleys: A study on its causes and consequences. *Natural Hazards Research*, 2(1), 33-40. https://doi.org/10.1016/j.nhres.2022.01.001

Suhr, F., & Steinert, J. I. (2022). Epidemiology of floods in sub-Saharan Africa: a systematic review of health outcomes. *BMC public health*, 22(1), 1-15. https://doi.org/10.1186/s12889-022-12584-4

Taloor, A. K., Thapliyal, A., Kimothi, S., Kothyari, G. C., & Gupta, S. (2022). Geospatial technology-based monitoring of HAGL in the context of flash flood: A case study of Rishi Ganga Basin, India. *Geosystems and Geoenvironment*, 1(3), 100049. https://doi.org/10.1016/j.geogeo.2022.100049

Thaler, T., Clar, C., Junger, L., & Nordbeck, R. (2021). Opportunities and challenges for transdisciplinary research in flood risk management: some critical reflections and lessons learnt for research on sustainability. *Eco.Mont (Journal on Protected Mountain Areas Research)*, 13(2), 42-47. https://doi.org/10.1553/eco.mont-13-2s42

Tuniyev, B. S., & Beregovaya, S. Y. (1993). Sympatric Amphibians of the Yew-box Grove, Caucasian State Biosphere Reserve, Sochi, Russia. *Asiatic Herpetological Research*, 5, 74-84.

United Nations Office for Disaster Risk Reduction [UNDRR] (2020). The Human Cost of Disasters: An Overview of the Last 20 Years (2000-2019). https://reliefweb.int/report/world/human-costdisasters- overview-last-20-years-2000-2019. Accessed 16 June 2022

Venkataramanan, V., Packman, A. I., Peters, D. R., Lopez, D., McCuskey, D. J., McDonald, R. I., ... & Young, S. L. (2019). A systematic review of the human health and social well-being outcomes of green infrastructure for stormwater and flood management. *Journal of Environmental Management*, 246, 868-880. https://doi.org/10.1016/j.jenvman.2019.05.028

Wagner, S., Souvignet, M., Walz, Y., Balogun, K., Komi, K., Kreft, S., & Rhyner, J. (2021). When does risk become residual? A systematic review of research on flood risk management in West Africa. *Regional Environmental Change*, 21(3), 1-18. https://doi.org/10.1007/s10113-021-01826-7

Wang, D., Zhou, Y., Pei, X., Ouyang, C., Du, J., & Scaringi, G. (2021). Dam-break dynamics at Huohua Lake following the 2017 Mw 6.5 Jiuzhaigou earthquake in Sichuan, China. *Engineering Geology*, 289, 106145. https://doi.org/10.1016/j.enggeo.2021.106145

Westgate, M. J. (2019). revtools: An R package to support article screening for evidence synthesis. *Research synthesis methods*, 10(4), 606-614. http://doi.org/10.1002/jrsm.1374