Mental Health Vulnerability Index (MHVI): preparing communities, societies and authorities for the impacts of climate change on mental health

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Executive Summary

RATIONALE:

Climate change poses a significant challenge to mental health and well-being both on local to global spatial scales and on immediate and long-term temporal scales, for instance, individuals who experience flooding are shown to have more persistent experiences of mental health conditions three years after the event than those who do not experience flooding (Mulchandani *et al*., 2020). Currently, Early Warning Systems (EWS) and Disaster Risk Reduction (DRR) strategies attempt to overcome challenges which are increasing because of the increased frequency and intensity of climatic hazards. Therefore, to ensure that EWS and DDR strategies continue to work in an era of growing climatic variability, this report undertakes an analysis of the current literature and policy of EWS and DRR strategies and proposes a novel solution (MHVI) to help a range of agencies identify communities most vulnerable to developing mental ill health during climatic hazards. This is to facilitate the implementation of solutions with are more anticipatory rather than responsive to help improve community resilience to the mental health implications of climate change.

KEY ISSUES:

Despite there being a significant body of literature within DRR medicine and EWS discussing the impacts of climate change and climatic hazards on public health, there are limited bodies of information which exist about the importance of integrating understanding about mental health in EWS. The gap is evident on a UK and global level. For instance, Moore *et al*. (2024) note the complexity of integrating mental health knowledge into methane warning infrastructure due to the integration of complex multi-method data and the difficulties in engaging with marginalised communities to ensure inclusive access to such infrastructure. Furthermore, even though there are significant numbers of different indexes to estimate the impact of various socio-economic, health and environmental issues, there is a notable lack of indexes to estimate the risk environmental hazards pose to mental health, despite the growing literature body indicating that climate change poses a substantial risk to mental health. For example, Charlson *et al*. (2021) highlight the lack of information about mental health outcomes within the current Climate Change Vulnerability Index and in low to middle-income countries and communities perpetuate inequalities in mental health care access during climatic hazards. Proving this literature review and the development of MHVI to be vital in helping to adapt EWS, DRR, government and health care infrastructures and communities for further future climatic variability.

> "... there is a notable lack of indexes to estimate the risk environmental hazards pose to mental health, despite the growing literature body indicating that climate change poses a substantial risk to mental health."

LITERATURE REVIEW:

The review analysed 55 pieces of literature, policy and general reports surrounding the themes of climate change, mental health, DRR and EWS following a Preferred Reporting Items for Systematic Reviews or Meta-Analyses (PRISMA) selection process. The review identified six key thematics: vulnerability to mental ill health during climatic hazards; mental health care within DRR strategies; current healthcare-related risk indexes; current climatic EWS; and the inclusivity and consideration of mental health. The review provided significant clarity on the current gaps in the literature and suggested areas for future research, outlined below.

THE MHVI:

The MHVI was developed as a novel index because of the lack of indexes available to measure the vulnerability of a community developing a mental health condition during climatic hazards, following the review of the literature.

The MHVI is a composite index made up of **five core themes** (socioeconomic vulnerability; hazard and exposure; population health: Mental health; Natural Environment; and Health & General Infrastructural Resilience) and **47 different indicators**, aiming to help support decision-makers, emergency services and public health officials to identify community vulnerability to developing mental illness during climatic hazards.

The MHVI was developed in the context of UK healthcare systems and experiences of climatic hazards. Therefore, the MHVI can more specifically aid UK health systems by:

- Helping to establish the level of community vulnerability to climatic hazards and mental ill health.
- Providing support to policymakers to better understand mental health vulnerability.
- Enabling the fulfilment of the Sendai targets, particularly of priority 4 33(O) and helps to determine the implementation of DRR strategies.
- Identifying emergent inequalities in mental health vulnerability to climate hazards, for example, between persons with and without disabilities.

The MHVI is applicable on a regional level and can help better understand regional climatic and healthcare-based nuances which global indexes fail to capture. The following ways MHVI can help highlight localised nuance include:

1. Highlighting areas with limited resilience capacity to allow for targeted interventions by local Authorities before, during and after a hazard to mitigate the associated mental health risks of climatic hazards.
2. Helping determine areas which can be focused on to increase community resilience.
3. Monitor the dynamic changes in levels of mental health resilience and vulnerability.

The methodology for calculating the MHVI was applied through the context of Wales and the Welsh Local Health Board system, allowing the index to be applicable UK-wide.

KEY FINDINGS AND RECOMMENDATIONS:

The Literature Review and MHVI revealed multiple important findings, providing key recommendations to furthering DRR and EWS mental health and climate change intervention.

The key findings and recommendations are as follows:

- There are many EWS and DRR indexes to address climatic hazards, but there has been limited consideration of mental health care within such strategies, both in a UK and global context.
- EWS and DRR indexes often use a top-down approach or if they do provide mental health care, it is often over a short-term period, particularly if they are research projects with limited funding or the care is provided by aid organisations. This can increase a community's risk of developing mental ill health conditions, through the lack of continuity of care in a community.
- Top-down approaches can lead to a lack of consideration for community mental health needs, leading to an increase in mental ill health risks and can perpetuate inequalities against 'vulnerable' groups.
- The MHVI is a simple and effective solution which has been created to help policymakers, emergency services and aid organisations in the UK and at a devolved level identify communities at greater mental ill health risk, and to implement strategy before hazards happen to reduce instances of mental ill health.
- The MHVI proves the possibility of helping develop anticipatory EWS and DRR strategies in the UK, which improve community resilience to the mental ill health impacts of climate change.
- More interdisciplinary research needs to happen surrounding community agency, vulnerability and mental ill health on a long-term basis, with stable funding to work in co-partnership with MHVI. This will help develop anticipatory solutions which support communities' needs and prevent the perpetuation of inequalities against vulnerable groups.

"The MHVI is a simple and effective solution which has been created to help policymakers, emergency services and aid organisations in the UK..."

Context

Climatic disasters have become an ever-present feature in the lives of communities across the globe due to the accelerated warming of global temperatures during the 21st century (Stein and Stein, 2022). This has led to greater numbers of people experiencing flooding, droughts, tropical storms, heat waves and forest fires (Morganstein and Ursano, 2020), leading to the loss of relatives, property and livelihoods (Berberian *et al.*, 2022). Furthermore, rising temperatures have also increased the risk of physiological damage, particularly to the brain (Lawrance *et al.*, 2021). Therefore, climate change has contributed to an increase in cases of anxiety (MB24.3), depression (6A7Z), Post-Traumatic Stress Disorder (PTSD) (6B40), dementia (6D8Z) and eco-distress – through witnessing environmental degradation in the media or having first-hand experiences of climatic disasters (Hickman et al., 2021), particularly after climatic-induced hazards (Morganstein and Ursano, 2020). This is illustrated in figure 1.

Climate change's impact on mental health and well-being emerged as a research area as early as 2009 but has only begun to emerge to the fore as recently as 2020, particularly within intergovernmental policymaking and disaster risk reduction literature (Corvalan *et al.*, 2022). DRR strategies aim to mitigate the impact of the disaster on communities, by either providing interventions such as training to community members before a disaster or facilitating the provision of aid and evacuation measures (Twigg, 2015). DRR strategies can be implemented for any form of hazard, ranging from floods and tropical storms to armed conflict (Weichselgartner and Pigeon, 2015). Climate change has altered how DRR is implemented by, for example, changing how aid is distributed because the increased intensity of climatic hazards can complicate aid distribution (Kelman, 2015). For instance, the increasing intensity of hurricanes is causing greater damage to infrastructure, such as airports resulting in delays in aid delivery or aid not being delivered (Obeagu, Ubosi and Uzoma, 2023). Henceforth, rendering the current disaster risk strategy useless because the strategy is not resilient enough to cope with the hazard (Kelman, 2015). DRR frameworks by intergovernmental organisations, such as the United Nations Office for Disaster Risk Reduction (UNDRR), have outlined the need to provide mental health care within disaster zones (UNDRR, 2024). One such

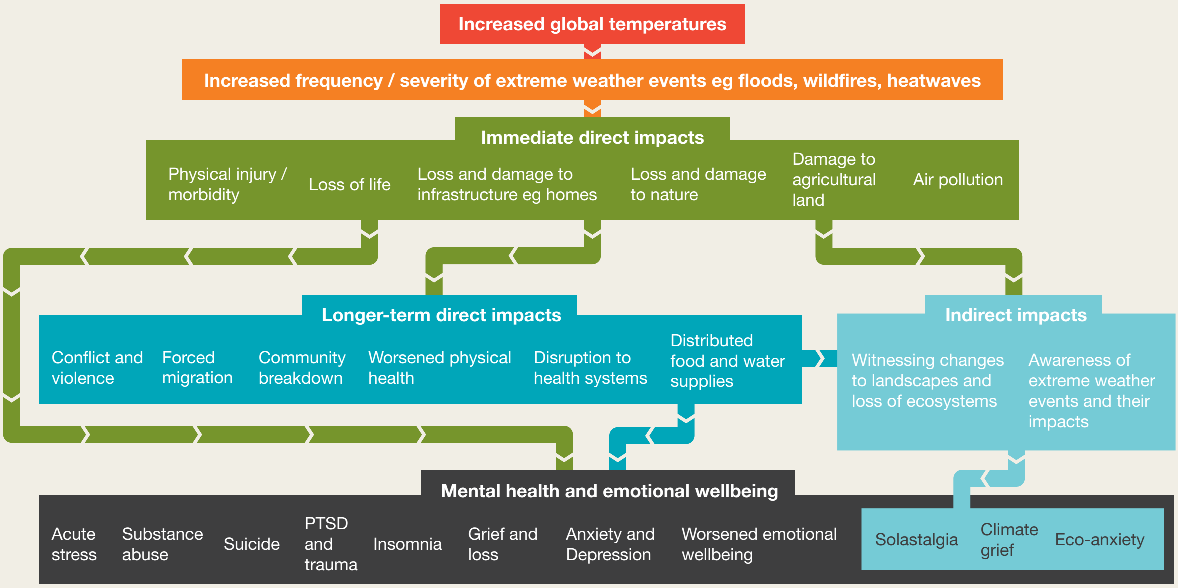
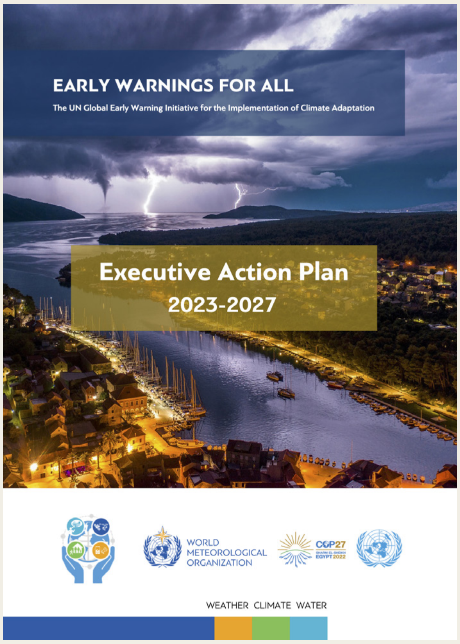


Figure 1: Lawrance et al. (2022: 450) diagram illustrates how climatic-induced hazards can increase the prevalence of mental health disorders

framework is the Sendai Framework (2015–30) with priority 4 33(O) stipulating the need *“to enhance recovery schemes to provide psychosocial support and mental health services for all people in need.”* (UNDRR, 22:2015). Intergovernmental organisations and community-led disaster risk reduction strategies have attempted to integrate mental health care into their strategies into their risk reduction plans (James *et al*., 2020). Mental health care has been implemented by providing community resilience training to administer mental health first aid and having on-the-ground mental health response teams with aid workers, such provisions have been made available by Médecins Sans Frontiers (MSF) ensuring each ground-based medical team has trained mental health nurses and a psychiatrist (James *et al*., 2020; Hambrick *et al*., 2023). However, this is not the only aspect of DRR.

Risk indexes also play a vital role in disaster risk reduction strategies, to help inform the types of interventions required for specific disasters (Eckstein *et al*., 2021). Risk indexes are used to quantify the level of risk a specific hazard poses to a community, allowing governmental and non-governmental organisations to direct and guide resources in the face of a hazard (Eckstein *et al*., 2021). Healthcare data has been used in disaster vulnerability indexes as well as in vector-borne disease-based risk indexes for illnesses, such as malaria (Vanhuysse *et al*., 2023). This has enabled Authorities to implement disaster reduction measures to reduce community transmission and susceptibility to vector-borne illnesses and save lives (Epstein *et al*., 2023). Risk indexes can also help to inform other disaster responses.

EWS are separate mechanisms and can aid in disaster risk reduction strategies. EWS are a single interconnected mechanism which monitors, forecasts, and predicts hazards informing hazard assessment, communication and reduction mechanisms allowing for governments, healthcare systems and communities to be as prepared as possible for a hazard (UNDRR, 2024). EWS can be used for all types of natural and human hazards, can help prevent the loss of life, and is used by decision-makers to inform policy decisions and actions (Guzzeti *et al*., 2020).



Climate change-based early warning mechanisms have been developed to incorporate emergency mobile phone text-based notifications and involve the contributions of both scientists and community leaders (Haque *et al*., 2024). Policymakers in intergovernmental organisations have promoted early warning mechanisms to ensure that warnings are accessible to all (Linares *et al*., 2020). One such example is the UN-led Early Warnings for All Executive Action Plan 2023–27 (WMO, 2022), co-produced by the World Meteorological Organization which lays out mechanisms to ensure that warning systems are more widely available and accessible to communities globally (Glantz and Pierce, 2023).

Climate change-based disaster risk reduction and early warning research have come to the fore in academic circles emphasising providing the necessary care after a disaster, and understanding how warning systems can better be developed to support community mental well-being (Gray *et al*., 2020). This literature review aims to highlight the current research which has been conducted to understand community vulnerability to mental ill health; the integration of mental health care into disaster risk reduction and early warning strategies; and the gaps within this body of literature.

“Risk indexes also play a vital role in disaster risk reduction strategies, to help inform the types of interventions required for specific disasters.”

Methodology

Papers and literature were found using Google Scholar published between 2014 and January 2024. The following search terms and phrases were used to source the review materials:

'disaster risk reduction mental health strategies'; 'mental health EWS'; 'aid organisational mental health care provision'; 'climate change and mental health'; 'EWS'; 'climatic EWS'; 'UN mental health disaster responses'; 'disaster risk indexes'; 'climatic intergovernmental disaster risk reduction policy'; 'climatic disaster risk indexes'; 'healthcare risk indexes'; 'accessible EWS'.

The search included articles in all languages, but English-language-only papers were selected due to my limited fluency in other languages. There were date searches of all dates; after 2020; after 2022; and after 2023 to ensure the most recent articles were used in the review. The review contains policy briefs; academic journal articles; NGO reports and book chapters. Papers were excluded if they mentioned mental health but did not include any possible solutions or actions taken to reduce the risk of developing mental illness. Healthcare indexes relating to vector-borne diseases were included as the literature review aims to understand the effectiveness of the risk index system rather than analysing the illness for which it is applicable. To select the research papers used in this literature review a PRISMA diagram was developed. PRISMA is an acronym for Preferred Reporting Items for Systematic Reviews or Meta-Analyses which is a method of undertaking transparent literature reviews, showing the reader how literature was screened for suitability during the literature review process, through a PRISMA diagram (Sarkis-Onofre *et al.*, 2021), see figure 2 below:

Overall, 55 papers were selected for this study covering various topics including disaster risk reduction policy, psychiatric disorders, healthcare-based risk indicators and EWS. The research was based on various spatial scales across the global north and south. The papers selected are comprised of reports, academic papers and policy briefs.

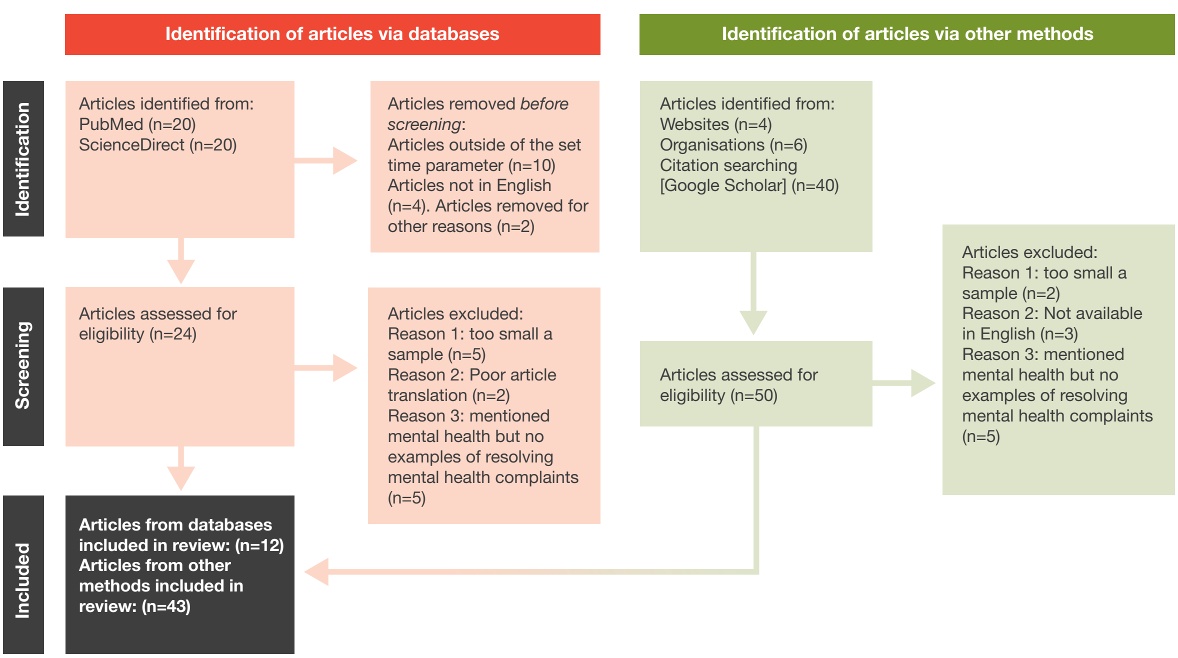


Figure 2: PRISMA diagram to show the methodological process of paper selection (Author, 2025)

Literature Review Findings

VULNERABILITY TO MENTAL ILL HEALTH DURING CLIMATIC HAZARDS:

Understandings of vulnerability to mental ill health have emerged from DRR, EWS and public health literature and show vulnerability to be caused by a variety of social, economic, environmental and demographic factors (Walkling and Haworth, 2020), triggered by both the primary (direct) and secondary (indirect) impacts of climatic hazards to public health (UKHSA, 2023). This has been explored in detail within DRR and public health literature, for example, through the works of Ebi *et al.* (2021) and Rocque *et al*. (2021). However, the literature lacks appropriate solutions that apply interdisciplinary thinking to address vulnerability to mental ill health and the primary and secondary public health impacts that emerge during a climatic hazard, such as a flood.

Literature indicated that vulnerability is determined by four main factors: health; socioeconomic; demography; and environment (Houston *et al.*, 2021). Health factors can determine vulnerability by displaying individual and community abilities to evacuate and recover efficiently after hazard events. Hence, data on the prevalence of mental illness and physical/sensory/cognitive disability are important in suggesting the capacity and potential to exacerbate current conditions and develop new conditions (Connon and Hall, 2021). Moreover, socioeconomic data can be vital in determining resilience, in terms of having economic and cultural resources to prepare and recover from hazards, thus, poverty, homelessness, financial and housing precarity, amount of household insurance, level of education and fluency can determine how vulnerable the community is and its ability to recover after a hazard event (Chakraborty *et al.*, 2020). Furthermore, demographics are key as they also determine the ability of individuals to evacuate, or recover 'well' post-hazard, or increase their risk of developing mental ill health. Demographics which have been deemed at the highest risk are: youth (under 25s) and elderly (over 65s) populations (Ige-Elegbede, Powell and Pilkington, 2023), women (particularly pregnant women), ethnic minorities, Indigenous communities and persons with disabilities (Connon and Hall, 2021). Environmental factors and urban design play a considerable role in increasing vulnerability, with heavily urbanised areas being prone to surface runoff; residential areas constructed on flood plains or are prone to coastal erosion; and intensive agriculture leading to increased soil compaction, amplifying the risk of surface runoff, and water abstraction, enhancing the risk of drought (Chateerji, 2022). Thus, the four areas of health; socioeconomic; demography; and environment demonstrate how climatic hazards could disproportionately affect specific populations, diminishing their resilience, meaning greater interventions will be required to ensure that positive health and well-being are maintained during climatic hazard events.

Consequently, vulnerability can influence the direct and indirect public health impacts of climatic hazards (Mahesar *et al.*, 2024). Direct public health impacts are created by the hazard itself, for example, in the case of flooding it would be floodwater being contaminated with harmful chemicals or carrying debris which could cause injury, including broken bones and skin and gut infections (Kovats *et al.*, 2021). For example, the 2000 extreme fluvial flooding in Lewes, South England, UK, reported a significant risk of gastroenteritis dependent on the depth of flood water as well as ear infections, caused by water contamination (Reacher *et al.*, 2004).

Whereas indirect public health impacts are not directly attributed to the hazard but emerge either before or following the hazard due to the damage to amenities, infrastructure, property and livelihoods as well as the potential loss of relatives and friends (Mulchandani *et al.*, 2020) population growth and urban development. The longer-term mental health impacts of flooding are not well understood. In 2015, the English National Study of Flooding and Health was established to improve understanding of the impact of flooding on health and inform future public health action. For example, the study showed common indirect public health impacts following flooding in the UK are secondary diseases spread by lack of sanitation; and mental ill health conditions, such as PTSD (6B40), anxiety (MB24.3) and depression (6A7Z) following witnessing damage and trauma associated with the hazard (Mulchandani *et al.*, 2020) population growth and urban development. Edwards, Gray and Hunter

(2015) show that during the severe drought across the Australian continent in 2007 there was a substantial increase in mental ill health conditions in farming communities, with 25.1% of farmers running farms with diminished productivity experiencing mental ill health. Therefore, Reacher *et al*. (2004) and Edwards, Gray and Hunter (2015) both highlight that the primary and secondary impacts of climatic hazards can have severe consequences on public health.

However, for those communities with higher levels of vulnerability, the direct and indirect health impacts of climatic hazards pose greater health-based challenges, leaving individuals at either a greater risk of developing mental ill health conditions or having current underlying comorbidities exacerbated by such impacts (Cianconi, Betrò and Janiri, 2020). For example, persons with disabilities are twice as likely to develop mental health conditions post-climatic hazard events because of the lack of accessible evacuation procedures and being displaced for longer periods because of the lack of infrastructure to facilitate entry into the community (Kosanic *et al.*, 2022). Thus, having a measure to indicate vulnerability/resilience to mental ill health could help support current evidence and identify areas of greatest need.

Despite the pressing need for interconnected solutions to address vulnerability factors and direct and indirect public health impacts, current health and DRR strategies and literature fail to provide solutions to bridge the 'gap' between both phenomena (Fraser, Aldrich and Small, 2021). Khan *et al*. (2018) highlight the lack of DRR-based research and that health and non-health-related public services have limited resources to be able to facilitate interconnected interventions. Gaps can be shown when examining specific climatic hazards, such as floods, as well as more generally particularly on a national, rather than international level (Imperiale and Vanclay, 2021). For example, Thomas and Niedzwiedz (2024) highlight how Scottish flood policy often lacks consideration for public health mechanisms and does not discuss the health implications of flooding on specific vulnerable groups, such as persons with disabilities, and that neglecting such nuances can lead to the widening of inequalities between communities, perpetuating discrimination (Bailie *et al.*, 2022). Thus, the literature needs to be expanded to develop interconnected solutions to ensure specific vulnerable groups are accounted for and have adaptation solutions in place, to reduce the risk of developing mental ill health.

MENTAL HEALTH CARE WITHIN DRR STRATEGIES:

Current DRR strategies that implement mental healthcare within their practices either tend to implement short-term and basic mental healthcare (top-down global disaster response) or provide community resilience training to facilitate long-term community-led mental health support (Aitsi-Selmi *et al*., 2015; Chan, 2017). However, these tend to be on a small scale and trial-led basis for academic research, rather than being provided on a larger scale to have a universal impact (Shah *et al*., 2020).

The literature highlighted that non-governmental organisations (NGOs), such as Médecins Sans Frontières (MSF), often have within their on-the-ground disaster response healthcare teams a psychiatrist and two mental health nurses (Tarannum *et al*., 2019). This is intended to relieve the stress on local healthcare facilities, particularly if they have been damaged or could not cope before the climatic event (Ibragimov *et al*., 2022). Disaster mental healthcare guidance is guided by academic research, and national and intergovernmental-supported policy briefs and initiatives (Mao and Agyapong, 2021). One such initiative is the World Health Organization (WHO), which developed a policy brief and session for the Stockholm50 summit in 2022 to help support countries to provide better psycho-social support and fill the gaps in academic research surrounding disaster risk reduction and mental health (Meier *et al*., 2022).

Furthermore, intergovernmental DRR strategies also use mobile technology and applications, such as Zoom and team-based counselling services, cognitive behavioural therapy apps[1] (CBT), and specialist remote trauma intervention (Lokmic-Tomkins *et al*., 2023). This has enabled more people to receive treatment for longer periods after the disaster and facilitated access to more specialist and acute treatment for those who need it

[1] *Cognitive behavioural therapy is a treatment which alters an individual's actions and moods by teaching coping mechanisms to change behaviour which is triggering low mood (Orengo-Aguayo et al., 2022).*

(Ruzek *et al*., 2016). Projects using mobile technology have been trialed in global north-based countries, due to the availability of technological infrastructure and applications in the local languages (Lokmic-Tomkins *et al*., 2023). One example was the implementation of SonomaRises during the 2017 Northern Californian bushfires, which helped users measure post-traumatic-related symptoms and daily mood; the app then provided exercises to manage these and lasted in severe power outages (Heinz *et al*., 2022). Overall, of the 1,049 users, there were over 949 visits to the stress reduction pages, which provided activities to reduce anxiety (MB24.3) (Heinz *et al*., 2022). There was also a trial with 7 young people aged 13-17, with 100% of the participants noting a decrease in their anxiety (MB24.3) after using the app (Heinz *et al*., 2022). However, further sampling would be needed to measure the app's effectiveness.

Literature has shown there are often too few clinicians for community needs, leading to the worsening of conditions, such as anxiety (MB24.3), depression (6A7Z), and PTSD (6B40), which has been shown to increase the risk of suicide and substance abuse (Tol *et al*., 2020). This is because medical teams are being shown to prioritise physical care over mental healthcare (Troup *et al*., 2021). This places greater pressure on healthcare systems which may have not fully recovered post-disaster, meaning more people wait longer for urgent treatment (Adesina *et al*., 2020). Moreover, policy writing has shown that despite the benefits of technological healthcare provision, improvement to infrastructure will be needed to ensure those who need it most can access the support, particularly through providing the internet (Cohen and Yaeger, 2021).

Disaster risk reduction academic literature on community-based resilience showed that there have been trials of providing community mental health resilience training to community leaders, such as doctors, teachers, police officers, and the clergy, to be able to provide support to people in need (Hambrick *et al*., 2023). Further to this, literature also showed that training was offered more generally to help people develop their coping strategies to manage associated symptoms of poor mental health when faced with natural hazards (Sri *et al*., 2023). This showed a decrease in the prevalence of anxiety (MB24.3) and depression (6A7Z) within the community generally, as well as when faced with disaster. However, these trials are very localized and have not been tested on a wider scale (James *et al*., 2020). Thus, to truly examine their impact, further literature would need to be written to deduce whether such community training would still have a significant impact on a wider scale, particularly as the main literature mainly focuses on global mental health disaster initiatives rather than localized community agency.

"Further to this, literature also showed that training was offered more generally to help people develop their coping strategies to manage associated symptoms of poor mental health when faced with natural hazards."

CURRENT HEALTHCARE-RELATED RISK INDEXES:

Academic development and literature surrounding healthcare-related risk indexes are either centralised on vector-borne diseases, such as dengue fever or malaria or have been developed to identify community vulnerability to a climatic hazard (Nathwani *et al*., 2021). Academic researchers have informed and developed risk indexes to be used by policymakers to shape decision-making surrounding mitigating the impact of climatic hazards (Vassiliou *et al*., 2020).

Vector-borne disease indicators are constituted of two key parts, transmission and susceptibility (Messina *et al*., 2019). Transmission constitutes the ability for the disease to spread, and susceptibility is the vulnerability of a population to be adversely affected by the disease (Zheng *et al*., 2020). Indicators to measure transmission tended to include population density per km^2, number of cases per km^2 etc. In contrast, susceptibility often includes household income, percentage of the total population over 65, homelessness, number of healthcare facilities per km^2 etc. (Baldoquín Rodríguez *et al.*, 2023). Literature showed that indexes tended to adopt open-source and free-access data, to ensure that the indexes could be easily replicated and tested (Eckstein *et al*., 2021). To ensure the data gaps were filled, the literature showed various methods to fill these gaps (Epstein *et al*., 2023). For example, using OpenStreetMap rather than Google Maps to locate properties and distributions of dwellings and asking local people how they move and access basic amenities in their local neighbourhoods (Vanhuysse *et al.*, 2023). Using open-source location data helps accurately understand the physical layout of a community and enables policymakers to develop localised disaster management responses, which could make a significant difference in saving people's lives (Shah *et al*., 2020).

However, these were often adopted on a localized level or were small academic studies which were dependent on temporary funding (Oladipo *et al*., 2022). Moreover, it can be a very difficult process to collect and find the essential data to be able to create risk indexes, particularly in countries in the Global South that lack the resources to collect such data (Alegana *et al*., 2020). Furthermore, mental ill health indicators were not adopted within any of the papers reviewed within the vulnerability aspect of the index (Clemens *et al*., 2022). This means the psychological vulnerability of a community to vector-borne disease, such as anxiety (MB24.3) surrounding catching the disease or bereavement surrounding losing loved ones, is not measured, nor accounted for (Clemens *et al*., 2022).

Vulnerability indexes were also shown to apply very similar indicators and methodologies as vector-borne disease indexes (Mochizuki and Naqvi, 2019). One such example is the INFORM index, a global humanitarian risk index, created by the European Commission (De Groeve *et al*., 2015). The INFORM index contains three key components: hazard & exposure (with environmental and human hazard subcategories); vulnerability (socio-economic); and lack of coping capacity (Institutional and Infrastructure) (Marin-Ferrer *et al.*, 2017). NGOs and intergovernmental organisations use INFORM on a global scale to determine a country's vulnerability and help dictate policy solutions (Chan *et al*., 2019). However, the index only contains basic healthcare infrastructure indicators, such as the number of hospital beds and diagnosis rates of malaria, which is not relevant for some parts of the world (Raikes *et al*., 2022). Thus, risk indexes containing healthcare indicators need significant further development to ensure that mental healthcare and well-being are adequately considered and accounted for.

CURRENT CLIMATIC EWS:

Within the literature, EWS in a climatic context have been explored in detail by academics and scholars (Owen, 2020). Climatic warning systems have been developed for flooding, droughts and heat waves (Esposito *et al*., 2022). Literature has been developed surrounding community-formed climatic EWS, but only in academia via small-scale studies, and humanitarian agencies such as the IFRC.

Flooding-based early warning research has been focused on the communication of warnings; the involvement of communities in developing warnings and providing education to both communities and policymakers (Perera *et al.*, 2020). This enables warning systems to be people-centric and beneficial to communities that need them as well as be able to communicate warnings (Glago, 2021). For example, Serba River, Niger has an early warning system developed in collaboration with the National Directorate for Hydrology in Niger and the University of Turin with the alert model being created 10 days before the event (Tarchiani *et al*., 2020). Community members are also trained to measure and monitor potential flood risks using colour-coded measurement poles and report the measurements to the national directorate (Tarchiani *et al*., 2020). Once reported, flood alert plans are communicated to the chiefs and community members through texts and radio transmission, to enable communication through local dialects and timely evacuation (Tarchiani *et al*., 2020). However, this communication system only alerts the community to the hazard but does not provide any form of guidance to access safe evacuation zones, which could have a detrimental impact on mental health, due to the stress of trying to reach higher ground (Linares *et al*., 2020). Furthermore, as the warning system uses a top-down approach, it does not provide the community with the opportunity to develop a warning system which is meaningful to their population (Budimir *et al*., 2020).

Literature also revealed that drought and heatwave-based EWS are dependent upon similar indicators (Lowe *et al*., 2011) and can be interconnected. Similar indicators include the level of rainfall for 28 days, vegetation health and UV ray intensity (Sutanto *et al*., 2020). This allows those using the warning system to be more clearly aware of the risks of both hazards and enables constant monitoring (Mukherjee and Mishra, 2021). One such example which uses this approach is the Northern Murray-Darling Basin, Australia, which uses the factors mentioned above as well as ones specifically interconnected with either droughts or heatwaves (Bhardwaj *et al*., 2021). This gives scientists and Authorities the chance to introduce disaster risk reduction initiatives earlier to mitigate the impacts on communities before a heatwave and/or drought (Ramón-Valencia *et al*., 2019). However, like the prior example, the Murray-Darling Basin warning system is very much a top-down strategy, which fails to include the community which lives within the basin in the chance to record the data (Bhardwaj *et al*., 2021). However, there are successful community-led climatic warning systems which are led from a ‘bottom-up’ approach and include all members of the community in their development to ensure a shared understanding of the meaning of the warning.

Despite not being commonplace, community-led climatic warning systems were highly effective in mitigating the impact of climatic hazards. The literature highlighted that community-developed warning systems were accurate as they are adapted to the local environment as well as created to be accessible in terms of language, evacuation provision and ease of receiving warnings (Macherera and Chimbari, 2016). Community-led climatic EWS were shown to be developed and implemented in academic research, for example, Smith *et al.* (2017) developed and tested a community-led flooding warning system in the Karnali Basin, Nepal. This warning system uses a computer-based model which was developed alongside the community and is dependent on sensors positioned in the river to measure water level and river flow, allowing the model to update itself, giving an instant result (Smith *et al*., 2017). The model also uses publicly available precipitation forecasts and data. If the model issued an alert, this triggered a warning siren across the village alerting people to evacuate to higher ground (Smith *et al*., 2017). However, such intervention is not commonplace within the wider implemented climatic early warning system interventions developed by intergovernmental and humanitarian organisations (Sahana *et al*., 2023). Moreover, de Cordoba Farini (2023) shows that currently, 86% of tested warning systems operate on a reactionary basis rather than a precautionary basis leading to communities having less time to evacuate. Reactionary basis warning systems fail to consider the underlying causes of a hazard which could be monitored and prevented from happening (Wever *et al*., 2022). Using responsive rather than anticipatory warning systems disproportionately impacts marginalised members of communities (Day and Fearnley, 2015), such as the disabled, who are more vulnerable to climatic hazards and require greater amounts of time to evacuate (de Cordoba Farini, 2023). Thus, further research will need to be conducted into the usefulness and mode of response of community-led climatic EWS, to better understand how to make climatic early warnings more inclusive. Despite this, other forms of inclusivity in early warnings have been analysed in academic literature, and policy solutions such as the Inclusive Early Warning Early Action Checklist (UNDRR, 2024).

INCLUSIVITY AND CONSIDERATION OF MENTAL HEALTH WITHIN EWS:

Academic Literature, reports commissioned by intergovernmental organisations and policy within the area of inclusivity and consideration of health is a newly emerging field in EWS research (Calagro *et al*., 2020). However, there is a considerable knowledge gap in considering mental health in climatic and disaster risk reduction-based EWS. During this literature process, no papers were able to be located on this topic.

Current EWS research's consideration of inclusivity is to ensure that those from low-income countries have access to warning infrastructure (Perera *et al*., 2020); women and indigenous peoples are involved in the development of warning systems (Mathathu and Seedat-Khan, 2022; Adade Williams *et al*., 2020); physically disabled people are considered within early warning system protocol, this includes work investigating prioritised evacuation and accessible emergency shelters (Stein and Stein, 2022; Kosanic e*t al*., 2022). Accessibility is understood to integrate disabled access (McBride *et al*., 2022), ensuring warnings are provided in local indigenous languages and dialects (Ahsan e*t al*., 2020); and transforming methods of communicating hazards, to ensure those who are illiterate can access warnings (Chisty *et al*., 2021). The integration of health considerations includes clear and easy-to-understand warning communications; sharing and signposting communities to healthcare support (Lovari and Bowen, 2020). Accessible EWS include basic and easy-to-understand language (Perera *et al*., 2020); systems which use symbols rather than written words to communicate risk (Guzzetti *et al*., 2020); contain information about evacuation plans which can be used by those with mobility impairments and communicate accessibility information about accessing evacuation shelters (Šakić Trogrlić *et al*., 2022). This research has been used by various researchers, intergovernmental organisations and policymakers to develop inclusive early warning research strategies which consider disability, indigenous language inclusion and individuals' health/well-being (Jodion *et al*., 2020; Leal Filho *et al*., 2022; Perera *et al*., 2020). Researchers have collaborated with multiple partners, such as intergovernmental organisations, to show research and policy gaps to create solutions (Yore *et al*., 2023).

Researchers have collaborated with policymakers to develop the Early Warnings For All (EW4All) Initiative, led by the World Meteorological Organization (WMO). This document is a 2023-27 executive management plan to ensure that EWS are accessible, implemented, and maintained for all communities and societies (WMO, 2022). The proposal is made up of four key 'pillars': disaster risk knowledge management, observations & forecasting, warning dissemination and communication and preparedness and response capacity; centred around the themes of access, data sharing and integrating data collecting capacity, how warnings are communicated and whether this is universally understood and being adequately prepared to be able to cope with such disasters (Glantz and Pierce, 2023). The WMO has dedicated $3.1bn to ensure that warning systems are implemented for all by 2027 (WMO, 2022). However, despite this initiative, it wants to improve EWS communication mechanisms (Li-Juan *et al*., 2024), EW4All faces challenges in adopting a people-centred approach, but to date, has neglected to include healthcare-based communication in warning (Fearnley and Budimir, 2023; Glantz and Pierce, 2023). Furthermore, the initiative also does not include the potential of making these warnings accessible to disabled people. Currently, warning systems are only accessible to <50% of the population, commonly associated with individuals in the Global North (UNDRR, 2024). However, there are even lower levels of access to warning systems for communities which are disabled/experience mental illness from the Global South (Gartrell *et al*., 2020). Thus, perpetuating inequalities in accessing and supporting community mental health during climatic hazards (Perera *et al*., 2020), placing into question whether this initiative is ensuring 'Early Warnings for All' (Glantz and Pierce, 2023).

Despite this, there are other significant research projects centred around the accessibility of EWS which seek to improve disability and illiteracy accessibility, indigenous language inclusion and healthcare.

One such project is the *Designing Inclusive, Accessible EWS: Good Practices and Entry Point* report commissioned by the World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR) and written by UCL's Warning Research Centre. This report explores current accessible practices in EWS (Yore *et al*., 2023). This project reflects on the current literature and projects which have been conducted globally to promote inclusivity on a grassroots level within warning systems. One example includes the Developing Risk Awareness through Joint Action (DARAJA)—The Inclusive City–Community Forecasting and Early Warning Service based in Kenya and Tanzania which works with marginalized communities, such as the elderly and disabled who live in informal housing, to improve weather and climate alert services (Yore *et al*., 2023).

Furthermore, there have been small-scale academic studies conducted, such as Pyke and Wilton's 2020 study, which assessed Ontario, Canada's early warning and disaster risk reduction systems for disabled people which included providing communication leaflets in braille and screen reader-accessible websites. This guidance only focused on visually impaired people, fundamentally excluding a significant majority of the disabled population within Ontario, such as those with learning disabilities.

Other academic research does show there are EWS concerning mental health, but these detect other mental health disorders, such as bipolar, rather than in the field of disaster risk reduction and climatic hazards (Bos *et al*., 2022; Kunkels *et al*., 2021). Mental health EWS are used to mitigate risks, such as suicide risk, and initiate healthcare interventions to prevent patient deterioration (Zheng *et al*., 2020). Thus, integrating mental well-being initiatives associated with looking after mental health into disaster and climate hazard EWS is a concept which has not been explored before. Consequently, a separate literature review with identified research priorities will need to be developed to facilitate possible research integration into climatic disaster risk reduction and early warning strategy.

"... integrating mental well-being initiatives associated with looking after mental health into disaster and climate hazard EWS is a concept which has not been explored before."

Key Gaps and Future Research

This literature review has uncovered several key literature gaps which require significant further research to better understand how to improve mental healthcare provision in disaster risk reduction and early warning system infrastructure. Firstly, seeking out more interconnected ways of understanding vulnerability and direct and indirect impacts of hazards on public health, especially on specific minorities, such as persons with disabilities, as noted by Thomas and Niedzwiedz (2024) to develop effective policy interventions. Currently, there is a notable literature gap within this area in the field of DRR, meaning more vulnerable communities are more susceptible to developing mental ill health post climatic hazards. So, to attempt to reduce such inequality gaps further research needs to adopt an interdisciplinary approach to creating interconnected solutions to examine inequalities and public health hazards from multiple environmental, social and economic perspectives.

Secondly, exploring the further potential of using community agency and action to strengthen mental health resilience on a larger scale, rather than a localised trial (as demonstrated by James *et al*., 2020) is needed. Once these trials are withdrawn, communities are left unsupported which means despite receiving this training, the skills will get lost progressively over time by individuals forgetting their training or moving out of the area (Hemachandra *et al.*, 2021). Thus, leaving the community as vulnerable as the trial started. So, to prevent this from happening having greater involvement and funding from intergovernmental organisations either being willing to try and integrate community training approaches into their DRR approaches or supporting large-scale research investigations into this area can help fill this knowledge gap.

Moreover, despite there being a significant number of healthcare and vulnerability-related indexes, there is currently no evidence of a Mental health vulnerability index being available to assess the vulnerability of a community to developing mental illness in the face of a climatic hazard. Therefore, as climate change is posing a significant threat to mental health and well-being, having an index is a significant priority to mitigate the impact of climate change on mental health and help guide research into better incorporating mental healthcare into disaster risk reduction strategies and early warning system communication. This will help achieve interdisciplinary collaboration between disaster risk reduction and early warning system researchers, policymakers, clinicians and the community and ensure a risk index is developed which can be useful to all.

Furthermore, despite climatic warning systems being more widespread and innovative in using multiple shared indicators (particularly for heatwave and drought warnings), more collaborative studies in community-based EWS are required, and not only within academic research. Therefore, further studies involving intergovernmental organisations and their provision of warning systems which use a community warning approach need to be conducted. This is to better understand the impact of community-based climatic EWS and to see if they provide a better approach to facilitating the effective and inclusive communication of warnings than current top-down interventions.

Finally, literature scoping highlighted a significant lack of research on the integration of mental health in EWS. Consequently, there is little known on how to create warning systems that integrate mental healthcare or support wellbeing during a climatic-induced hazard/s. So further systematic reviews of this topic and studies which provide solutions would need to be developed both within academic and non-academic (i.e. policymaking and NGO) sectors to fill this gap. Further to this, the current work on attempting to make DRR and EWS accessible and inclusive is also limited in specific areas, for example, only focusing on physically disabled people and limited work on the translation of warnings into Indigenous languages (Thompson *et al*., 2020). Thus, further work by academics alongside intergovernmental organisations will need to be conducted to further identify how to better ensure inclusion amongst groups which are still being excluded within 'inclusive' DRR and early warning system design.

Key Findings and Recommendations

This literature review has shown the various research contributions and ways in which mental healthcare has been integrated into disaster risk reduction and EWS research and responses.

In this article, there are 55 different papers which have been used to inform this systematic analysis. These were selected by the screening process as outlined in the methodology section and included two policy briefs, three intergovernmental reports and 50 academic articles. These highlighted current initiatives, gaps in the research and potential solutions in integrating mental health and mental healthcare into DRR and EWS. The key findings and recommendations of the literature review are shown in Figure 3.

The key finding from analysing these articles is that mental health is not being considered in many aspects of DRR and EWS research. Firstly, despite vulnerability and the direct and indirect public health impacts of climate change being discussed extensively, the lack of interconnected solutions in mitigating mental ill health impacts leads to the perpetuation of inequalities against groups classed as 'vulnerable' such as persons with disabilities.

Secondly, Mental health care provided by the DRR is a superficial and short-term response. There have been attempts to include technology to improve care quality and community resilience as shown by some small-scale academic studies. However, this has not been explored further, so, literature and solutions need to be developed

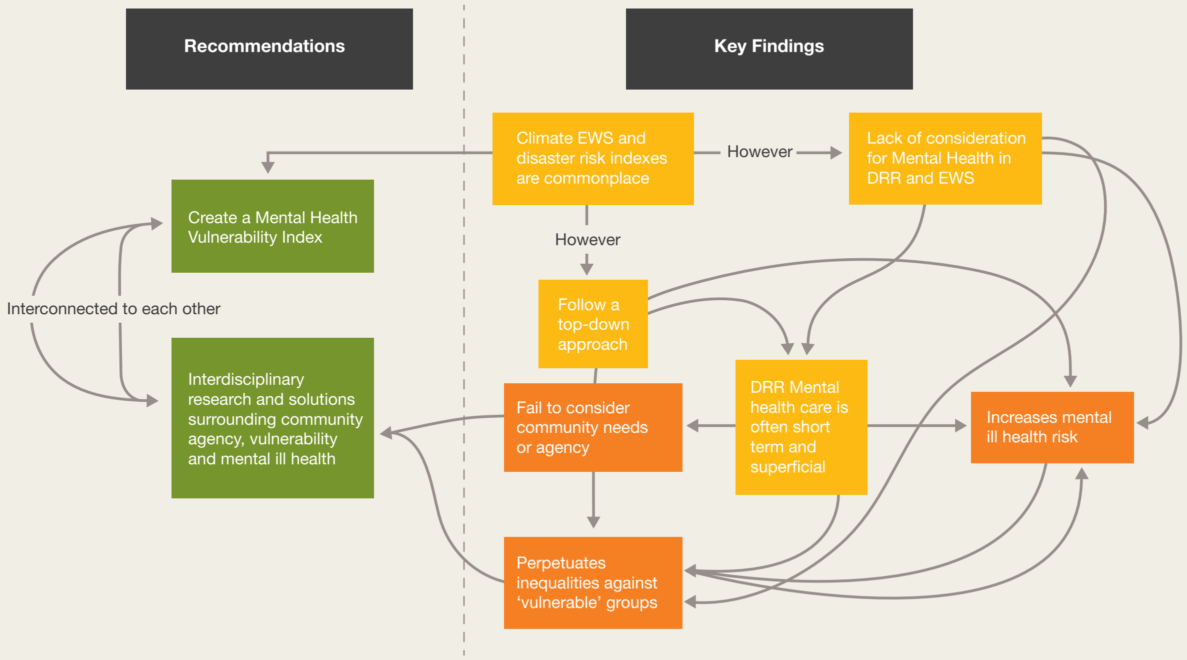


Figure 3: A diagram to show the key findings and recommendations of this literature review (Author, 2025)

to explore the possible impact of community agency in reducing the risk of community members developing or worsening mental illness.

Furthermore, there are a variety of disaster risk indexes for community vulnerability and specific illnesses, such as malaria, but nothing around measuring the risk of community members developing mental illness or the capacity for psychiatric and general healthcare to cope with climatic disasters. Therefore, academic research needs to be guided towards facilitating the creation of a Mental health vulnerability index to help policymakers prepare healthcare services to cope with potential uptake in mental healthcare before, during and after climatic disasters.

Moreover, climatic EWS are commonplace, particularly relating to floods, droughts, and heat waves. However, these tend to use a top-down governance approach which often delimits the community's ability to have agency over measuring and producing warnings. Therefore, further community-based EWS research needs to be conducted on a wider scale within intergovernmental settings to improve understanding of how the representation of communities within EWS can change and enhance current early warning infrastructure.

Finally, even though inclusivity has started to be considered in a wider range of marginalized communities, such as Indigenous and physically disabled people. There is considerable literature 'silence' surrounding mental health, mental healthcare and mental illness considerations within EWS. Thus, there is a huge scope to expand and investigate how mental health as a subject area can be incorporated into current community, intergovernmental and top-down EWS.

Overall, despite there being significant research gaps, this poses a significant and exciting opportunity to develop and innovate how mental health care is provided and integrated into disaster risk reduction and early warning system initiatives. The process of reviewing literature inspired the development of this resilience index to help better understand and integrate mental healthcare into EWS and help prepare for climatically induced hazards.

> "... there are a variety of disaster risk indexes for community vulnerability and specific illnesses, such as malaria, but nothing around measuring the risk of community members developing mental illness or the capacity for psychiatric and general healthcare to cope with climatic disasters."

Building a Mental Health Vulnerability Index

WHY WAS THIS INDEX DEVELOPED?

This index will better understand the health-based vulnerabilities of a population, particularly their mental health vulnerability to better prepare communities, social and emergency services; healthcare leaders and providers; and local and national governments for natural and human-based disasters to prevent further mental health decline. Currently, research in health-based risk management indexes focuses on physical illnesses, such as malaria and dengue fever, rather than mental illness (Kulkarni *et al*., 2022). This is important, particularly during an era of significant climate change as these diseases are controlled by the earth's climatic conditions, so populations are better prepared to deal with outbreaks (Messina *et al*., 2019). However, physical health is not the only aspect of human health impacted by rapid climate change (Marks and Hickman, 2023). Intergovernmental organisations, such as the IPCC recognise climate change's impact on mental health and well-being in their recent AR6 report by noting: "Climate change is expected to have adverse impacts on well-being and to further threaten mental health (very high confidence)" (Cissé *et al*., 1046:2022).

Thus, having a mental health vulnerability index is important to mitigate the impact of climate change on those who already have mental health disorders and attempt to reduce the risk of others developing mental illnesses post-disaster. Having an index for mental health risk will help fulfil the Sendai framework Priority 4 33(O) and Early Warning for All (2023–27) initiative. Therefore, adopting a risk index which prioritises mental health within international disaster risk reduction will help communities, medical services and governance structures become more resilient to the impacts of climate change on their mental health and wellbeing.

CURRENTLY APPLIED INDEXES IN INTERNATIONAL DRR:

There are two internationally adopted indexes for disaster risk reduction, these are the WorldRiskIndex and the INFORM index. The WorldRiskIndex was developed by Birkmann and Welle (see Birkmann et al., 2011) for The Alliance Development Works. The WorldRiskIndex aims to communicate different levels of risk and vulnerability of communities globally, simply and effectively (Ramli *et al*., 2020). The index is calculated using four key areas exposure (exposure to the hazard); susceptibility (vulnerability of the population); lack of coping capacity (how a society limits the impact of a disaster); lack of adaptive capacity (how a society copes in the long-term after a disaster) (Welle and Birkmann, 2015), producing a score out of 100 with five risk categories (very low – very high) (IFHV, 2023).

The second risk index is the INFORM index, a global risk index which is openly available to be used in humanitarian risk response, developed by the European Commission (De Groeve *et al*., 2015). The INFORM index considers three key areas of disaster risk: hazard & exposure (with natural and human subcategories); vulnerability (socio-economic and vulnerable people); and lack of coping capacity (Institutional and Infrastructure) (Marin-Ferrer *et al*., 2017). These have subcategories and the risk model is displayed in Figure 4 (overleaf).

The index generates an overall score from 0 (no risk) to 10 (very high risk) which can also be applied on a regional basis (Marin-Ferrer *et al*., 2017). The provision of the different levels of dimensions, categories and components as shown above allows those using the indicator to immediately understand the risks which will need to be addressed during a natural hazard-generated disaster (Chan *et al*., 2019).

However, despite these two indexes being comprehensive in their outlook on hazards and vulnerability, they fail to explore the impact of climate change more widely on health and healthcare facilities, let alone mental health resilience (Gray *et al*., 2020). Thus, the following section shall propose a vulnerability index based on the structure of the INFORM index but will better integrate and prioritise healthcare and mental health into disaster risk indexes. MHVI is a novel proposal which has been developed as a solution following the identification of relevant gaps in the literature and currently applied indexes, to help identify communities most vulnerable to developing mental ill health after a climatic hazard event.

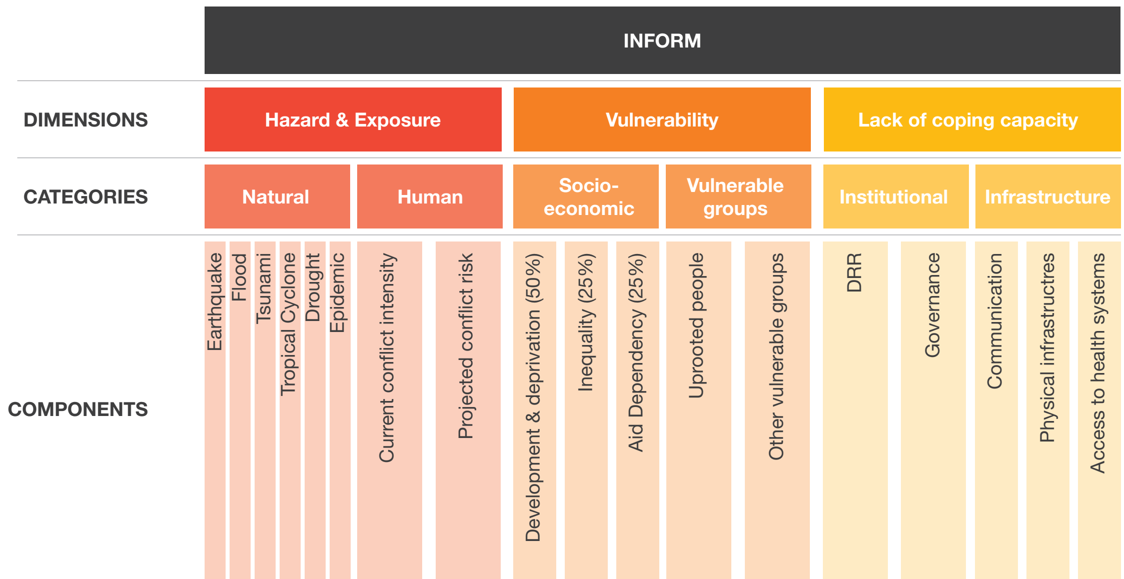


Figure 4: A diagram illustrating the INFORM risk index (INFORM, 2017, p12)

MENTAL HEALTH VULNERABILITY INDEX:

The Mental Health Vulnerability Index (MHVI) is a tool that can be used to understand individuals' vulnerability to mental ill health before, during and after climatic hazards. The objective of the MHVI is to highlight the areas at risk of climatic hazards and have the highest levels of mental health vulnerability. This enables communities, authorities and healthcare providers to mitigate the impacts of such risks, build community resilience and better prepare and recognise the implications of climate hazards on mental wellbeing.

The MHVI provides a specific focus on:

- Helping to objectively understand the level of community vulnerability to climatic hazards and mental ill health.
- Provide support to policymakers to better understand mental health vulnerability.
- Enables the fulfilment of the Sendai targets, particularly of priority 4 33(O) and helps to determine the implementation of DRR strategies.
- Identify emergent inequalities in mental health vulnerability to climate hazards, for example, between persons with and without disabilities.

MHVI applies on a regional scale to better understand the localised nuances of climatic hazards, health vulnerability, and distributions of healthcare resources and expertise, which globalised indexes often neglect. MHVI can be applied in three keyways to show the localised nuances of mental health vulnerability:

1. Highlight areas with limited resilience capacity to allow for targeted interventions by local authorities before, during and after a hazard to mitigate the associated mental health risks of climatic hazards.
2. Helps determine areas which can be focused on to increase community resilience.
3. Can be used to monitor the dynamic changes in levels of mental health resilience.

Applying the MHVI can provide an overview of current levels of mental health resilience to climatic hazards. However, the MHVI is a composite index, which simplifies the reality of mental health resilience. Thus, MHVI needs to accompany other localised data and information for decision and policy-making during climatic hazards to help monitor how resilience capacity can change throughout hazard events.

UK APPLICATION OF MHVI:

The MHVI prototype is based on climatic disasters and healthcare systems in the United Kingdom (UK). MHVI aims to support UK-based health Authorities, local governments, and communities in mobilising better mental health support and mitigating the risk of developing mental illnesses, such as anxiety (MB24.3), depression (6A7Z), and PTSD (6B40), before, during, and after climatic-related disasters.

The index has been informed by key literature and provides five core areas: socio-economic vulnerability; hazard and exposure; natural environment; population health; healthcare and general infrastructure resilience. 53 indicators are combined within the index to produce an overall risk score. The risk score will be out of 10 for each local Authority (0 (no risk) and 10 (highest risk)) and will be updated daily and before, during and after the hazard event and in the face of changes to availability to vital infrastructure, such as electricity and clean water. A general score will be issued seasonally, to monitor changes in general risk because of changing weather patterns. This will provide accurate and up-to-date information for the Authorities and mental health professionals to monitor resilience and can help direct relevant funding and resources to areas most in need across the UK.

CONCEPTION OF MHVI:

Literature has shown overwhelmingly that climate change is having a negatively detrimental impact on mental health and well-being and provides methods to address these concerns. Thus, the methods of creating this index have been informed by core literature produced by psychiatrists surrounding the risk of developing mental health disorders after disasters and climate change's impact on mental health; susceptibility of communities to mental illness; using foundational disaster risk conceptional literature; risk indexes developed for other health conditions, such as malaria; and frameworks which consider the coupled relationship between humans and the environment (Ward et al., 2020). The index also incorporates methodologies used by the INFORM index; Cardona *et al*., (2012) conception of vulnerability; children's pain management indexes ; and literature from community-led EWS .

Cardona's (2012) conception of vulnerability shows vulnerability to be made up of exposure to the hazard but, it may not automatically equate to risk. If the area is protected adequately or a building is designed to cope with the hazard, this is exposure, but to make a community 'vulnerable' to a hazard they need to be 'exposed' (Cardona *et al*., 2012). The second aspect is how 'vulnerable' a community is to a hazard, this could be demonstrated through social vulnerability, such as the number of disabled people/refugees and the prevalence of specific mental/physical illnesses etc.; infrastructural vulnerability, such as quality of roads, number of hospitals and availability of emergency services per 100,000 people; and economic vulnerability through the level of unemployment, amount of disposable income and levels of deprivation. The higher prevalence of vulnerable groups, lack of quality infrastructure and lower levels of disposable income can make communities extremely vulnerable (Raikes *et al*., 2022).

Children's pain management indexes are shown to include colour and facial expressions to allow for the clear communication of pain to healthcare professionals (Zieliński *et al*., 2020). The visual prompts of facial expressions and colour help children to quantify and understand their pain level (Lawson *et al*., 2021). Therefore, these forms of indexes are vital to ensure all community members, such as intellectually disabled people, can understand the threat a climatic hazard poses to them and help them understand what is going on around them. This could be vital in aiding emergency

[2] *This will enable the index to be accessible and easily accessible for all members of the community, such as children under 10 and intellectually disabled people, to be able to understand and mentally prepare themselves for how the climatic hazard could change their lives (Pertiwi et al., 2020).*

[3] *Community-led and implemented warning systems are shown to be more widely respected, inclusive of community-based knowledge and give communities agency over managing warning systems (Macherera and Chimbari, 2016). Community-led warning systems can help the authorities and scientists also better understand the nature of hazards on a localised level and change how they communicate hazards on a national level (Baudoin et al., 2016).*

services and caregivers to help explain why they are being evacuated or why there has been damage to their home, keeping them aware of what is going on and mitigating potential distress.

Community-led EWS enables community agency and helps understand hazards on a localised level, informing scientists of potential hazards which could emerge and would not necessarily be flagged on a national warning system (Perera *et al*., 2020). This enables the production of systems which work best for communities, healthcare professionals and local Authorities, such as using local languages or dialects of the national language to promote understanding and overcome infrastructural challenges, such as limited mobile phone signal (Moises and Kunguma, 2023). This will be important in considering the devolved diversity in the UK to ensure the index is accessible, by providing the system in Welsh and Gaelic, and that it not being dependent on mobile phone signals in rural areas.

Therefore, to incorporate all the aspects of hazards, all components of the index will be equally weighted in the same fashion as the INFORM index. The index includes Cardona's conception of Vulnerability; is inspired by indexes which are used by children to make the index accessible; and incorporates community agency to ensure it works for local people. Below is how the index is calculated by combining the different aspects of socio-economic vulnerability; hazard and exposure; population health; healthcare infrastructure and general infrastructure resilience; and the natural environment.

$$\textbf{Risk Index Score} = \frac{\textbf{SEV + HE + PE + NE + HGIR}}{\textbf{5}}$$

SEV = Socio – Economic Vulnerability

HE = Hazard and Exposure

PE = Population Health

NE = Natural Environment

HGIR = Healthcare and General Infrastructural Resistance

Figure 5: Risk index calculation (Author, 2025)

The risk index calculation has been performed like this to consider indicators which have not been previously integrated into other international warning indexes. For example, in socio-economic vulnerability and population health, other indicators will be included surrounding loneliness and dementia to consider elderly populations' vulnerability and mental illness risk. This has been done as the UK has a rapidly ageing population which will become less resilient to climate-related disasters, for example, there has been a 57.3% increase in elderly people dying due to heatwaves (Watts *et al*., 2020).

Those who experience loneliness are more likely to experience climate anxiety and mental illness (Hajek and König, 2022), with climatic disasters shown also to accelerate deterioration in dementia symptoms (Zuelsdorff and Limaye, 2024). Furthermore, the natural environment section will apply natural daylight hours to consider the impact of seasonal depression in amplifying mental illness risk, particularly on those who live further north in the UK, such as in the Scottish Highlands, or are dependent on the agricultural, fisheries and forestry sectors for employment (Drew *et al*., 2021). This is to ensure the index is more locally adapted to the UK's demographic and natural environment but provides an initial template to test, and may be adapted for other national contexts. This report tests the index in a Welsh national context.

MHVI VISUALISATION:

The mental health vulnerability index is made of multiple components and produces an overall risk score from the 47 indicators which make up the 5 aspects of the overall risk index. Each risk aspect has two subcategories which help filter the relevant indicators into groups. One indicator is simply not reflective of overall risk so having a variety of indicators can help generate the most detailed picture of the overall level of risk. The index is illustrated below (Figure 6).

CONTRIBUTION OF MHVI TO DRR AND EWS:

There are several key reasons why this index is unique in the field of DRR and EWS. Firstly, this index has a specific focus on mental health and uses indicators which solely represent mental illness, particularly surrounding the prevalence of mental health disorders within a community. Thus, making it a key tool in reducing the risk of developing mental health problems in the face of climatic-induced disasters. Secondly, the index intends to be used in a local context due to the types of data used within the index, particularly when referring to impacts on infrastructure, as well as specific socio-economic data, such as the WIMD (Index for Multiple Deprivation), allowing risk to be measured on a local level, rather than many vulnerability indexes that focus on the global scale (Agbahadji *et al*., 2023). Moreover, having localised data will allow the relevant community to update the index to make the value more representative for them, particularly surrounding land use type and infrastructure, and representing the amenities and economic structure of the area, as these data sets are often infrequently updated or have even been created on a national level (Kumar et al., 2021). The Local Health Board (LHB) defines the localised level due to data availability limitations for healthcare and infrastructure factors. Once data availability has improved it aims to be paired to the local level. Furthermore, the index will change daily during a climatic hazard event or whether major basic infrastructure, such as electricity, internet and sanitation has been damaged, to allow for a more accurate risk assessment. This enables the Authorities to better prepare for and direct resources for those in need. This index has also been planned to include an accessible alternative for learning disabled and young children to help them prepare for climatic-induced disasters. Finally, the seasonal release of risk index scores has been integrated to accommodate seasonal mood changes, due to the change in daylight hours which alters mood increasing the risk of depression (6A7Z) (Galima et al., 2020). the local level. Furthermore, the index will change daily during a climatic hazard event or whether major basic infrastructure, such as electricity, internet and sanitation has been damaged, to allow for a more accurate risk assessment. This enables the Authorities to better prepare for and direct resources for those in need.

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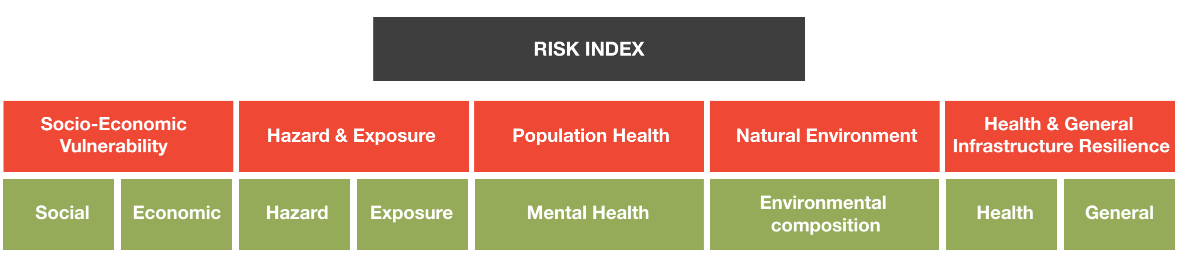

Figure 6: Risk Index component layout (Author, 2025)

Process

Indicators are often selected based on statistical and population value (usefulness of an indicator to a specific community group) (Peitz *et al.*, 2021). To test the index's effectiveness, Wales was used as a trial country to see whether it could be implemented UK-wide. Furthermore, the devolved nation has the necessary data publicly available to make it easier for communities and Authorities in the future to follow this process and implement it in their local area.

Indicators for this report have been selected for their locational and socio-environmental value to the population who live in Wales. This section will outline the indicators which are used within each of the five components of the index. All indicators are normalised and inverted to a 0-10 scale with lower values to show lower population vulnerability to mental ill health and higher values to highlight a higher population vulnerability to mental ill health when faced with climatic hazards.

CASE STUDY:

Wales is a devolved nation within the United Kingdom (UK) with a population of three million people (Jones, Orford and Higgs, 2015). Wales has a mix of urban and rural environments, with most of the population residing in the south-east and along the northern coast (Sfyridis and Agnolucci, 2020).

The country has a considerable ageing population with 21.5% of the population +65 (Parry, 2023), and issues of poverty and deprivation both in rural and urban areas, with 12% of adults and 18% of children living in persistent poverty, which is higher than England, Scotland and Northern Ireland (ONS, 2022).

Wales also has accessibility issues with poor public transport and internet connection, particularly in rural areas (WIMD, 2019). Wales's governance is devolved with issues, such as health, education and housing being controlled by the Senedd (Welsh Parliament) with successive Labour governments being in charge since the devolution of Welsh politics in 1997.

HEALTH:

Wales has an increasingly unhealthy population because of the challenges posed by systemic poverty and inequality, with 34% of the population being classified as overweight or obese and high levels of premature deaths and substance addiction (Bone, 2024). Mental health is no exception with 23 in every 100 people in Wales having been diagnosed with a mental health condition (WIMD, 2019).

Certain parts of Wales have high suicide rates in the population with Powys recording a suicide rate of 26 out of 100,000 people taking their own life between 2022-23 (Public Health Wales, 2024). Health care in Wales is governed by seven Local Health Boards (LHBs): Betsi Cadwaladr, Aneurin Bevan, Powys Teaching, Hywel Dda, Swansea Bay, Cwm Taf Morgannwg and Cardiff and Vale University Health Board (Welsh Government, 2023). Each of these LHBs controls every aspect of NHS healthcare within their areas from Hospitals and GP practices to issuing prescriptions etc. (Welsh Government, 2023).

However, Wales's NHS is under constant strain and pressure due to ongoing junior doctors strikes and backlogs caused by the COVID-19 pandemic (Welsh Government, 2023). A map of the LHB coverage over Wales is shown below.

GIG CYMRU NHS WALES | Iechyd Cyhoeddus Cymru Public Health Wales

1. Betsi Cadwaladr UHB
2. Hywel DdA UHB
3. Powys UHB
4. Swansea Bay UHB
5. Aneurin Bevan UHB
6. Cwm Taf Morgannwg UHB
7. Cardiff & Vale UHB

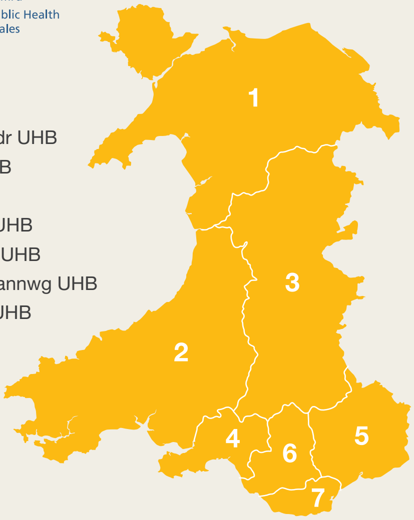

Figure 7: Map of LHBs in Wales. Source: Public Health Wales (2021)

CHALLENGES POSED BY CLIMATE CHANGE:

Climate change poses significant challenges to countries around the world and Wales is no exception (Climate Action Wales, 2024). Currently, 245,118 homes in Wales are at risk of flooding as of 2022 and climate projections show peak river flows of major rivers, such as the Severn, are set to increase by 25% by 2080 and rainfall intensity by 20% by 2080 which increases overall flood risk for communities who live in these areas (Welsh Government, 2021; NRW, 2022). Flooding is not the only risk climate change poses, sea level rise is also set to rise by 1.33m by 2100 in Southeast Wales (Cardiff, Newport and Monmouthshire), increasing the intensity of coastal erosion and flooding risk (Welsh Government, 2021). There is also notable evidence that Wales experiences a high number of small-scale wildfires, with Southeast Wales experiencing an average of 3,000 per year (Clements, 2021).

GOVERNMENT CURRENT ACTION:

The Welsh government has taken multiple measures to set climate targets and measure the impact of climate change on communities. The Environment (Wales) Act 2016 has noted that Wales is legally bound to become net-zero by 2050 by setting 10-yearly review targets and five-yearly carbon budgets (Climate Action Wales, 2024). Furthermore, the government aims to make the public sector, and the Welsh Government institutions net zero by 2030 (Climate Action Wales, 2024). The Welsh government has also paid attention to community mental well-being by asking people about how they feel about climate change and the risks posed by flooding in their annual National Survey for Wales, which interviews 12,000 people per year (Welsh Government, 2024), their recent 2022-23 survey indicated that 68% of 16-44-year-olds and 78% of 45-64-year-olds were very concerned or concerned about climate change (Welsh Government, 2024) and 46% over interviewees were very concerned or concerned about flooding in their local area (Welsh Government, 2024). Furthermore, the main public health body, Public Health Wales and the World Health Organisation Collaborating Centre on Investment for Health and Well-being have written a key report titled: *Climate Change in Wales: Health Impact Assessment Summary Report* (Edmonds and Green, 2023) which note that *"Climate change will have potential major, multifaceted, co-occurring and inequitable impacts … which will impact on the health and wellbeing of the whole population of Wales, and some population groups are likely to experience disproportionate negative impacts"* (Edmonds and Green 5:2023).

HOW THE INDEX COULD AID THE WELSH GOVERNMENT AND PUBLIC HEALTH WALES:

The index can be useful in multiple ways. Firstly, areas which are shown to be more prone to climatic hazards can be monitored more closely, to see whether the community's mental health is at a greater risk of being impacted by climate change. Secondly, the tool can help policymakers more effectively see whether there are gaps in healthcare provision where the population is more vulnerable due to socio-economic conditions or where the prevalence of mental ill health is highest. Moreover, the index shows the interconnections between the natural environment and mental health and well-being, and how the interconnections between climate change and mental health can disproportionately impact those who are dependent on the natural environment as a part of their livelihood, such as agricultural workers. Finally, the index can be useful as it can help LHBs adequately prepare services before hazards happen to ensure communities can be supported but also given the agency, through training and warning systems to be prepared to handle the hazard which in turn can reduce the risk of community members developing mental illnesses.

Index Sections

The following section outlines how the MHVI works on an LHB scale and how to calculate the individual components and overall MHVI. This section will explain how MHVI would work concerning Wales and the Welsh NHS care system, acting as an extension of the Wales case study. Extending the Wales case study is important as the MHVI can help Public Health Wales fulfil its first potential action addressed within its Climate Change in Wales Health Impact Assessment: Summary Report which is *“enhancing mitigation and adaptive capacity via long-term investment in preventive action”* (Edmonds and Green, 8:2023).

SOCIO-ECONOMIC VULNERABILITY:

To ensure governments, emergency services and communities are aware of their community composition, and how community composition can impact how they respond to natural hazards; a socio-economic vulnerability score needs to be calculated. The socio-economic vulnerability section is made up of social, health, demographic and economic indicators, which if faced with a climatic hazard could negatively impact community mental health.

There are two subcategories which will be calculated through geometric averaging: social vulnerability and economic vulnerability. The vulnerable groups targeted in the social vulnerability subcategory are seen to be at greater risk by healthcare professionals of developing or worsening their current state of mental or physical illness. The economic category is implemented to reflect how those who are financially precarious and lose their livelihood in a climatic-induced disaster are most vulnerable to developing mental illness.

DEFINING SOCIAL VULNERABILITY:

The key consideration when understanding social vulnerability is understanding the level at which individuals in a community are negatively affected by climatic hazards due to health, disability, age, social contact, race, immigration status etc. Those who are most at risk, particularly of mental illness, have poorer health; are either young children/adults or are elderly; have a disability; experience loneliness; are from an ethnic minority background; and are either seeking asylum or have been granted refugee status.

Due to systems of social inequality which operate in the UK based on race, class, gender and disability, these factors impact housing quality, medical resilience, and ability to source food and essentials, which in turn impact mental health. Those who are socially vulnerable are most likely to struggle with the multiple factors raised above, which in turn increases their social vulnerability further.

For example, if an individual who is disabled, or elderly experiences loneliness and has their home flooded, they are more likely to develop post-traumatic stress disorder because of lack of interaction before the climatic hazard, not being evacuated in a dignified manner, and losing the only familiar thing to them, their home (Levy *et al.*, 2024).

> “A key focus in disaster risk reduction strategies is reducing the impact of a natural hazard on a community’s health and well-being, particularly in the instance of mental health which is the main focus of this index.”

COMPONENTS OF SOCIAL VULNERABILITY INDICATOR:

Here are the indicators which are used within the social vulnerability indicator. To ensure each data set corresponds with each LHB area for the healthcare data, an arithmetic average will have to be taken for each local Authority within an LHB area for each characteristic. LHB areas have been selected as the healthcare data could not be scaled down. Once the arithmetic averages have been combined an overall geometric mean will be calculated. The indicators are in the table below.

Indicator	Source	Scoring system
Population under 12	Office for National Statistics (Census 2021)	Percentage of total population (%)
Population aged 12–25	Office for National Statistics (Census 2021)	Percentage of total population (%)
Population aged 65+	Office for National Statistics (Census 2021)	Percentage of total population (%)
The population who are disabled	Office for National Statistics (Census 2021)	Percentage of total population (%)
Communities living on flood plains or in areas with high levels of coastal flooding/erosion	Natural Resources Wales (2022)	Total number of high and medium-risk properties to flooding per LHB.
10-30% Most health-deprived communities in Wales – GP recorded mental health condition per 100 people	WIMD (Welsh Index of Multiple Deprivation) – 2019 Health	GP recorded mental health conditions per 100 people per LHB
Ethnic Minority communities	Office for National Statistics (Census)	Percentage of each minority group in the total population (%)
Refugees and Asylum Seekers	GOV.UK	Percentage of total population (%)
Veterans	Office of National Statistics	Percentage of the total population (%)
Percentage of the population who experiences loneliness	National Survey for Wales (Welsh Government (2024))	Percentage of population (%) who experience frequent loneliness

Figure 8: Table of social vulnerability indicators

DEFINING ECONOMIC VULNERABILITY:

Considerations made when understanding economic vulnerability often include the following. Firstly, the ability for an individual to afford to evacuate and re-build their lives post-hazard (Hallegatte *et al.*, 2020) for example, those who are unemployed or from deprived socio-economic backgrounds may not be able to afford the fuel to drive to an evacuation site (Deria, Ghannad and Lee, 2020) or not have content and housing insurance on their property, which means once the hazard has diminished, they are unable to rebuild their lives (Drakes *et al.*, 2021).

Secondly, whether the hazard influences their work, for example, farming can be directly impacted by pluvial flooding because of the damage to crops, soil erosion and loss of livestock (Yazd, Wheeler and Zuo, 2020), thus, leading to a loss of income which has been shown to have a direct impact on people's mental health (Batterham *et al.*, 2022).

Finally, the adaptability of a population to life after a hazard, including the ability for people to change jobs if they have lost them because of the damage caused by a hazard (Forrest, Trell and Woltjer, 2020). Changing jobs can be easier for those with a higher level of education (Brown and James, 2020), thus, those with limited qualifications are more likely to struggle with finding employment after a hazard which increases an individual's risk of developing a mental health problem (Charlson *et al.*, 2021).

COMPONENTS OF ECONOMIC VULNERABILITY INDICATOR:

The method outlined in the social vulnerability indicator will be applied in the same way as the economic vulnerability indicator. However, for the level of education, a further arithmetic average will need to be calculated as the data will be categorised separately, enabling the production of an overall average level.

Level of education will be categorised as 1 = no education to 4 = bachelor/advanced university level education e.g. Master's and PhD.

Indicators	Source of data	Scoring system
People in income deprivation (%)	Welsh Index of Multiple Deprivation 2019	1 = most deprived 6976 = least deprived
Level of Unemployment	Labour Market Data 2020/21	(%) percentage of unemployment
Sector employment	Labour Market Data 2020/21	Job sector distribution ('000s)
Level of education	Census 2021	Level 1: lower secondary school, such as O Level and GCSEs Level 2: higher secondary school, such as higher, advanced higher, A level or equivalent Level 3: college, such as HNC, HND, SVQ level 4 or equivalent Level 4: university degree or equivalent

Figure 9: Table of Economic vulnerability indicators

The socio-economic vulnerability score calculation process is illustrated below:

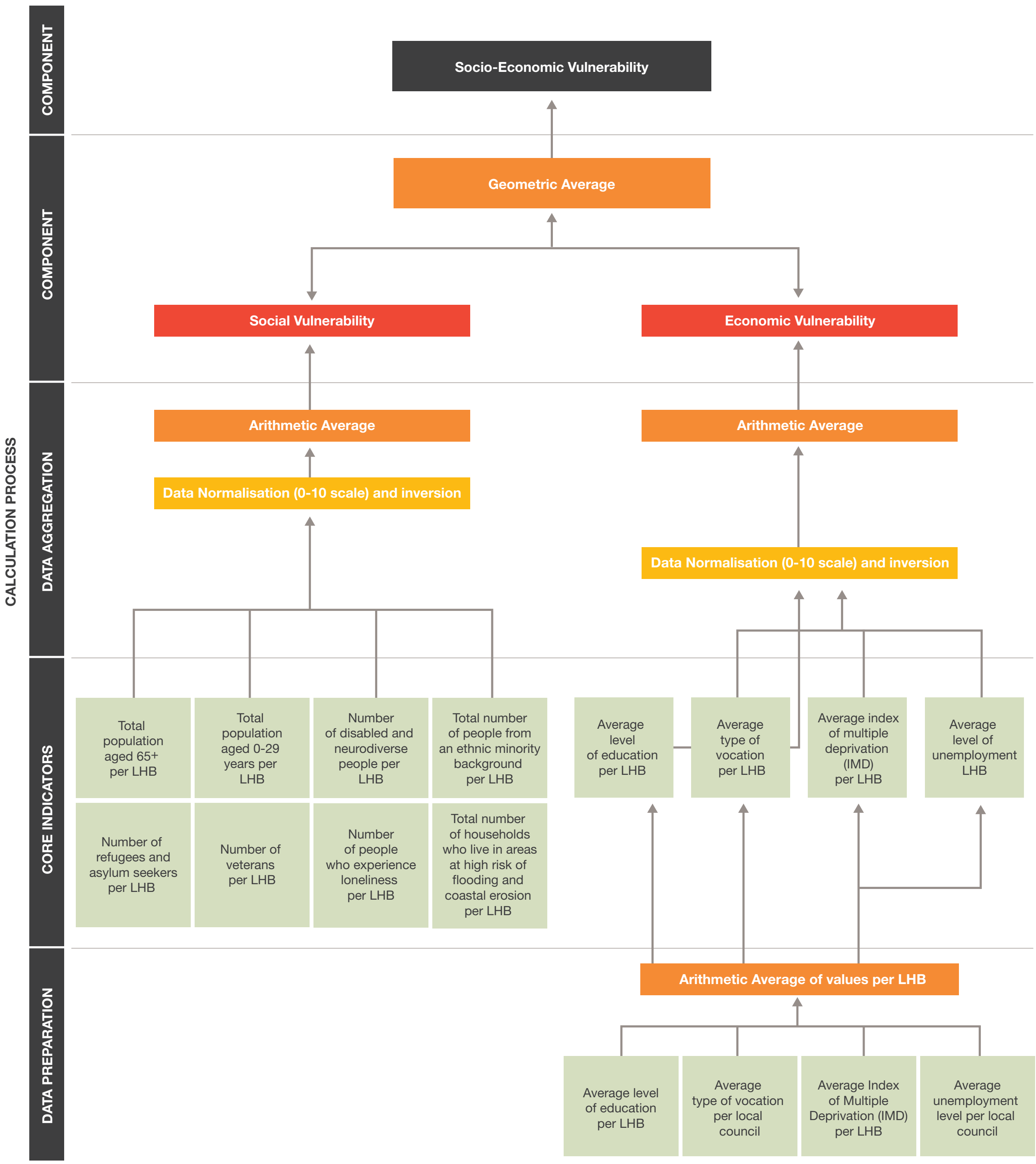

Figure 10: Visualisation of the calculation process (Author, 2025)

Explanation of calculating different values:
LOG (Absolute) – Total value of all normalised indicators added together.
Relative Value – Normalised indicators relative to the total population per LHB.

HAZARD AND EXPOSURE:

This section considers the likelihood of a population having contact with a natural hazard. If the population does not have contact with the hazard, there is no risk posed to the population (Ward *et al.*, 2020). Thus, hazard and exposure have been merged to show the intensity of the hazard which a community has to respond to. The data available was extensive to reflect the diversity of natural hazards experienced in the UK. When calculating the hazard and exposure component, it is split evenly between the type of natural hazard and the frequency they occur at every 1, 3 and 5 years.

CATEGORIES:

There are two subcategories within this section, the first of which is hazards which contain a variety of climatic hazards (for hazards included see figure 7) and exposure which shows the frequency of hazard events occurring in a specific area (Liu and Chen, 2021). The data is normalised and aggregated by a geometric mean of the two categories.

DEFINING NATURAL HAZARD:

Natural hazards damage property, and infrastructure and cause the loss of human life, these can lead to disasters, and increase people's risks of developing mental illnesses (Sharpe and Davison, 2021). Natural hazards, especially flooding make up for the displacement of millions of people per year globally (Kam *et al.*, 2021). Hazards can be both quick and slow moving with rapid-onset hazards, such as floods having different indicators to slow-onset hazards, such as droughts (Amirzadeh and Barakpour, 2021). Annual average exposures will be applied within this index due to the frequency of report releases by environmental agencies in the UK only being yearly (Bates *et al.*, 2023), but as data evolves this index can be updated daily.

However, there are tiers of severity within specific mapping indexes, for example, coastal and pluvial flooding risk maps which can allow for a more nuanced analysis of risk, whereas other maps just show the extent of the hazard. Certain data sets, particularly for droughts were difficult to access or find due to the lack of data collected across the UK, so to ensure a measurable result is generated the number and location of drought warnings over the past four years were collated together, rather than using a data set which has already been made as these are not currently available.

NATURAL HAZARD: COMPONENTS

The natural hazard category includes eight different hazards which will use an arithmetic average taken for each local authority within a LHB area for each characteristic. LHB areas have been selected as healthcare data cannot be scaled down. An overall geometric mean will be calculated. The geometric mean will be combined with the exposure components and normalized to produce an indicator between 0-10. The indicators are in the table below:

Indicator	Data set	Scoring system
Coastal and Pluvial Flooding Risk	Properties at risk of Flooding (2019) Stats. Wales	Overall number of high and medium risk properties
Coastal Erosion	Natural Resources Wales Flood and Coastal Erosion Maps (2024)	Overall number of high and medium-risk communities
Heatwaves	Historic Weather Warning Records (2018–2024) for England and Wales (Met Office)	Total number of Amber and Red weather warnings per area across the six years
Drought	UK Centre for Ecology and Hydrology, UK Water Resources Portal	Average drought indices for a 3-month accumulation period between 2020–24
Wildfire	England and Wales Fire Severity Index (2024) Met Office	Total number of High to excep-tional warning alerts per area
Landslide	National Landslide Database 1970–2024 BGS	Total number of landslides per region

Figure 11: Table of natural hazard indicators

WHY HAS EACH INDICATOR BEEN SELECTED?

Firstly, these hazards were selected as they are most likely to happen in the UK and are becoming more commonplace in the face of climate change (Bates *et al.*, 2023; Pandey *et al.*, 2023). Some events are far easier to predict, such as floods, the Welsh Government asks in their well-being survey about people's concerns about flooding and has extensive modelling programmes and alerts (Welsh Government, 2024).

However, other natural phenomena are becoming more commonplace which have a detrimental effect on community mental health and can be difficult to measure, such as drought and heatwaves, for example, hospital admissions for psychiatric disorders are shown to increase during heatwave periods (Ige-Elegbede, Powell and Pilkington, 2023). Thus, having a variety of possible natural hazards can cover various scenarios which could impact communities in multiple ways.

DEFINING EXPOSURE:

Exposure highlights the number of times an area or community may experience a hazard over a specific period, such as every year. The more a community encounters a hazard, the harder it is for the community to recover, due to the constant physical damage to property. It also has negative consequences on mental well-being (Walinski *et al.*, 2023). To ensure the changes in risk are properly captured and to better understand how often these events occur within a community, exposure to each type of hazard needs to be accounted for.

EXPOSURE: COMPONENTS

As the natural hazard category includes eight different hazards, exposure to each hazard needs to be accounted for so an arithmetic average is taken for each local authority within an LHB area per year. LHB areas have been selected as healthcare data cannot be scaled down. Once the arithmetic averages have been combined an overall geometric mean is calculated. This is combined with the natural hazard indicators and normalised to produce an indicator between 0-10. The indicators are in the table below: Why has a year interval been selected?

Indicator	Data set	Scoring system
High and Medium Coastal and Pluvial Flooding Risk	Properties at risk of Flooding (2019) Stats.Wales	Average number of high and medium-risk properties per year
Coastal Erosion	Natural Resources Wales Flood and Coastal Erosion Maps (2024)	Average number of high and medium-risk communities per year
Heatwaves	Historic Weather Warning Records (2018–2024) for England and Wales (Met Office)	The average number of Amber and Red weather warnings per area per year
Drought	UK Centre for Ecology and Hydrology, UK Water Resources Portal	Average drought indices for a 12-month accumulation period between 2023–24
Wildfire	England and Wales Fire Severity Index (2024) Met Office	Average number of High to exceptional warning alerts per year
Landslide	National Landslide Database 1970–2024 BGS	Average number of landslides per region per year

Figure 12: Exposure indicator table

WHY HAS A YEAR INTERVAL BEEN SELECTED?

A year interval was selected as multiple hazards can occur during the same time, such as a wildfire and drought or landslides and flooding, which can lead to greater exposure to hazards. This complexity needs to be captured within such a metric. Furthermore, there is a lack of data for specific indicators, such as the wildfire and heatwave indicators only provided a maximum of six years' worth of data, which makes it more difficult to create. However, further editions of the index seek to explore this possibility further for estimated projections for three and five years.

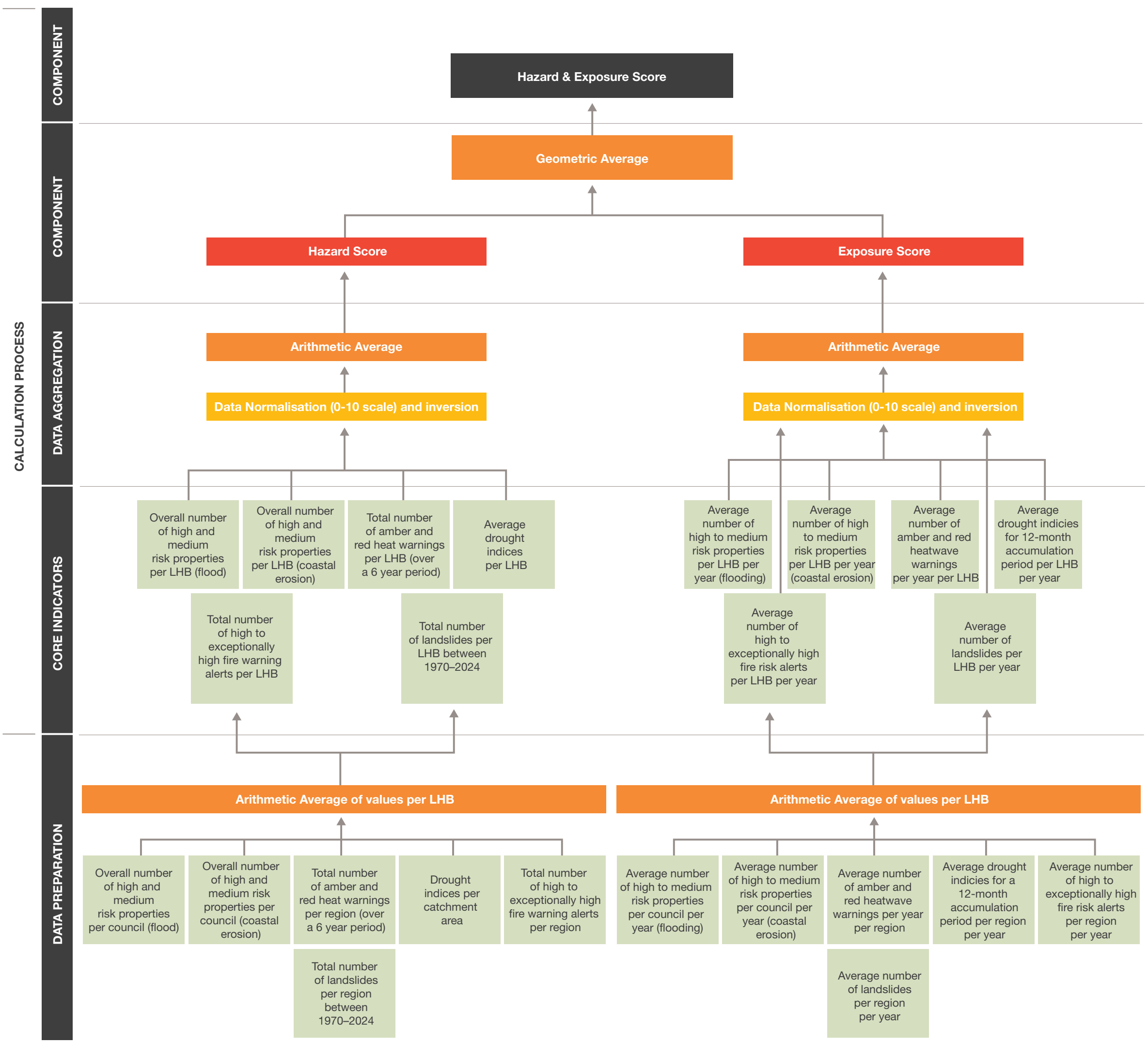

Figure 13: Calculation process for the hazard & exposure score (Author, 2025)

POPULATION HEALTH: MENTAL HEALTH:

A key focus in disaster risk reduction strategies is reducing the impact of a natural hazard on a community's health and well-being, particularly in the instance of mental health which is the main focus of this index.

The impact of hazards disproportionately impacts those from low socio-economic backgrounds, ethnic minorities (Rothschild and Haase, 2023), disabled communities, as well as areas which already have high comorbidity of mental health conditions (Clayton *et al.*, 2023), with disasters either leading to individuals developing mental illnesses or contributing to the deterioration of already prevalent mental health disorders (Charlson *et al.*, 2021).

The mental health aspect of the index therefore highlights the current prevalence of mental health conditions in each LHB; the current percentage of the population accessing mental health services; waiting times for mental health services; prescription rates of anti-depressants and anti-psychotics; in-patient hospitalization rates; substance abuse rate; suicide rate; the prevalence of dementia; and the gaps in the data can indicate the quality and accessibility of the health service.

CATEGORY DEFINITION:

This category has been created to show how current levels of mental healthcare use, the prevalence of mental health disorders and other health conditions, such as dementia and substance abuse can make communities more vulnerable to developing or worsening mental health conditions, particularly when facing a climatic hazard (Zuelsdorff and Limaye, 2024).

Thus, this category aims to show how mentally resilient communities are to climatic hazards and measure their ability to recover from the impact of an extreme weather event.

"A key focus in disaster risk reduction strategies is reducing the impact of a natural hazard on a community's health and well-being, particularly in the instance of mental health which is the main focus of this index."

MENTAL HEALTH COMPONENTS:

The mental health category includes ten different indicators using the overall totals of people diagnosed with specific mental health conditions etc. LHB areas have been selected as healthcare data cannot be scaled down. All data will be displayed per 100,000 people as most data sources are based on this format. An overall geometric mean of all the indicators will be calculated. The indicators are in the table below:

Indicator	Source	Scoring system	Data gaps
Prevalence of dementia within the population	General medical services contract (quality assurance and improvement frame-work): interactive dashboard GOV.Wales	Total number of diagnoses of dementia per LHB	0/7
Mental health medication prescription rates per year (2018–2024)	Primary care prescriptions: interactive dashboard GOV.Wales	Average number of mental health-related prescriptions issued per year per LHB	0/10
Prevalence of Mental health conditions per LHB within the population	Quality Assurance and Improvement Framework (QAIF) disease registers by local LHB Statswales	Total number of people diagnosed with a mental health condition per LHB	0/7
Substance abuse combined data for drugs and alcohol	Data mining Wales: The annual profile for substance misuse 2022–23 Public Health Wales	Total number of people on treatment in hospital for substance abuse per LHB	0/7
Referrals to mental health services (2023)	Combined Child and Adult psychiatric referrals per LHB (2020–24) Statswales	Total number of referrals 2023	1/10
Population accessing mental health services	Combined Outpatient and Inpatient attendances to adult and child psychiatric appointments (2018–19) Statswales	Total number of patients in outpatient and inpatient appointments.	0/7
Hospitalisation rate per LHB	Admissions to mental health facilities by local LHB (2020–21) Statswales	Total Number of people admitted to psychiatric facili-ties per LHB	2/10
Suicide Rate per LHB	Deaths by suspected suicide, by LHB area of residence. Public Health Wales	Death by suicide per 100,000 people	0/10

Figure 14: Population health – Mental health indicators

WHY WERE THESE INDICATORS SELECTED?

Firstly, those who already receive mental healthcare before hazards are more vulnerable to a deterioration in mental well-being, thus, these indicators reflect the general mental health of a population before a hazard event. This can allow local government and support organisations to prepare better-tailored support for those communities in terms of strengthening healthcare, emergency provision and evacuation procedures to reduce susceptibility to other mental health conditions, such as PTSD (6B40). Furthermore, having data about hospitalisations and referrals to mental health services highlights the quality of a mental health service. The score generated from these indicators can help LHBs know what resources they would need to prevent a breakdown in care for those already using services and provide swift intervention for those who develop mental health conditions during and after a natural hazard event.

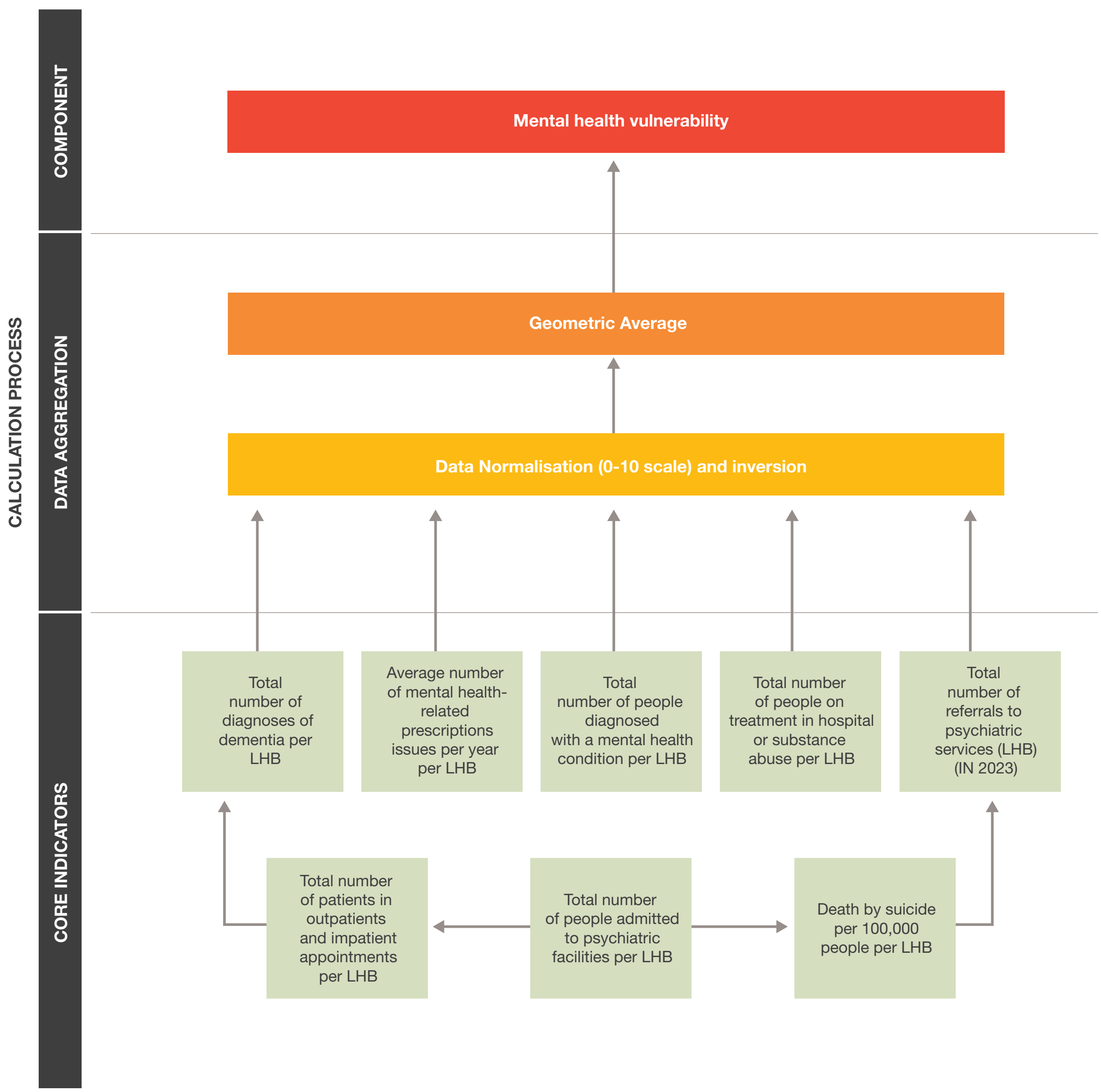

Figure 15: Diagram explaining population health score calculation (Author, 2025)

NATURAL ENVIRONMENT:

Having a better understanding of the environment can help in estimating the risk of a population developing a mental health condition. This is because environmental factors, such as soil types can exacerbate hazards, for example, porous sediments, such as sandstones, are more easily erodible (Pulley and Collins, 2024) which means during a coastal storm surge there is more likely to be further damage to property which can have negative impacts on community mental health (Quinn *et al.*, 2023).

Furthermore, the time of year such hazards occur can also have an impact on emotions, for example, during winter as there are far fewer daylight hours this increases the susceptibility of a population to experiencing low mood or depression (6A7Z) (Rosenthal, 2023). This is known as seasonal affective disorder (SAD) which currently affects an estimated 3 in 100 people in the UK per year (RCPsych, 2018).

Therefore, communities that experience hazards during the winter months are more likely to develop or have existing mental health conditions exacerbated by hazards (Cianconi, Betrò and Janiri, 2020). Communities that are even more susceptible include agricultural and low-income communities due to dependency on the natural landscape and lacking the resources to recover from such hazards compounded with the lack of daylight can lead to further negative mental health consequences (Cianconi, Betrò and Janiri, 2020).

> "Thus, these indicators can help authorities provide resilience strategies, such as mental health first aid training to community leaders to administer support to communities to help cope with the impact of climatic hazards..."

CATEGORY DEFINITION:

This category aims to highlight how the composition of the natural environment can have an impact on human mental health, placing a population at greater risk of developing mental health conditions (Shultz *et al.*, 2019).

By using daylight hours, land use and soil and sediment composition in an area can highlight potential vulnerabilities within communities, for example, Byan et al. (2020) have explored that farmers can be the most disproportionately affected by depression (6A7Z) and PTSD (6B40) due to the impact of the loss of livelihood.

Thus, these indicators can help authorities provide resilience strategies, such as mental health first aid training to community leaders to administer support to communities to help cope with the impact of climatic hazards, for example, farming consultants in Mississippi, USA, undertook mental health first aid training with 60% applying this training to their work and 15% used these skills to support farmers experiencing a mental health crisis (Shortland *et al.*, 2023).

NATURAL ENVIRONMENT COMPONENTS:

The natural environment section contains three main indicators using average daylight hours during a specific season, such as spring; overall land use type in a specific healthcare region; and average soil and sediment composition in a certain healthcare region. LHB areas were selected as the mental health data was not available on a smaller scale. Arithmetic means will be calculated for daylight hours for a specific season; land use type and soil/sediment compositions. Afterwards, these will be combined into a geometric mean to show that one factor can have a significant influence on the risk of an individual developing a mental health condition and then normalised. Indicators are displayed in the table below.

Indicator	Data source	Scoring system
Daylight Hours	Times for sunset and sunrise in the UK Worlddata.info	Average sunset and sunrise per month
Average river flow	UK Centre for Ecology & Hydrology – UK Water Resources portal	Mean and Actual river flow (m/s) values
Land Use	Wales Land Cover Map 2021 Edinburgh DigiMap	12 category land use overlay
Average Rainfall	UK Centre for Ecology & Hydrology – UK Water Resources portal	Mean and Actual Rainfall (mm)
Geology Map	Wales DiGi map Geology coverage EdiDigi Map	Bedrock, Dykes and Superficial deposits

Figure 16: Natural environment indicator table

> “Therefore, communities that experience hazards during the winter months are more likely to develop or have existing mental health conditions exacerbated by hazards.”

WHY WERE THESE CATEGORIES SELECTED?

Firstly, these categories were selected as they are key environmental factors that have been shown to have the most direct impact on human mental health and well-being (Cianconi, Betrò and Janiri, 2020; Pulley and Collins, 2024). Furthermore, other indexes currently associated with disaster risk reduction in the healthcare sector do not currently consider the role of the environment in impacting mental health (Sameroff and Seifer, 2021). So, incorporating the environment can show how human-environmental interconnectivity can greatly influence mental health, particularly during a climatic hazard.

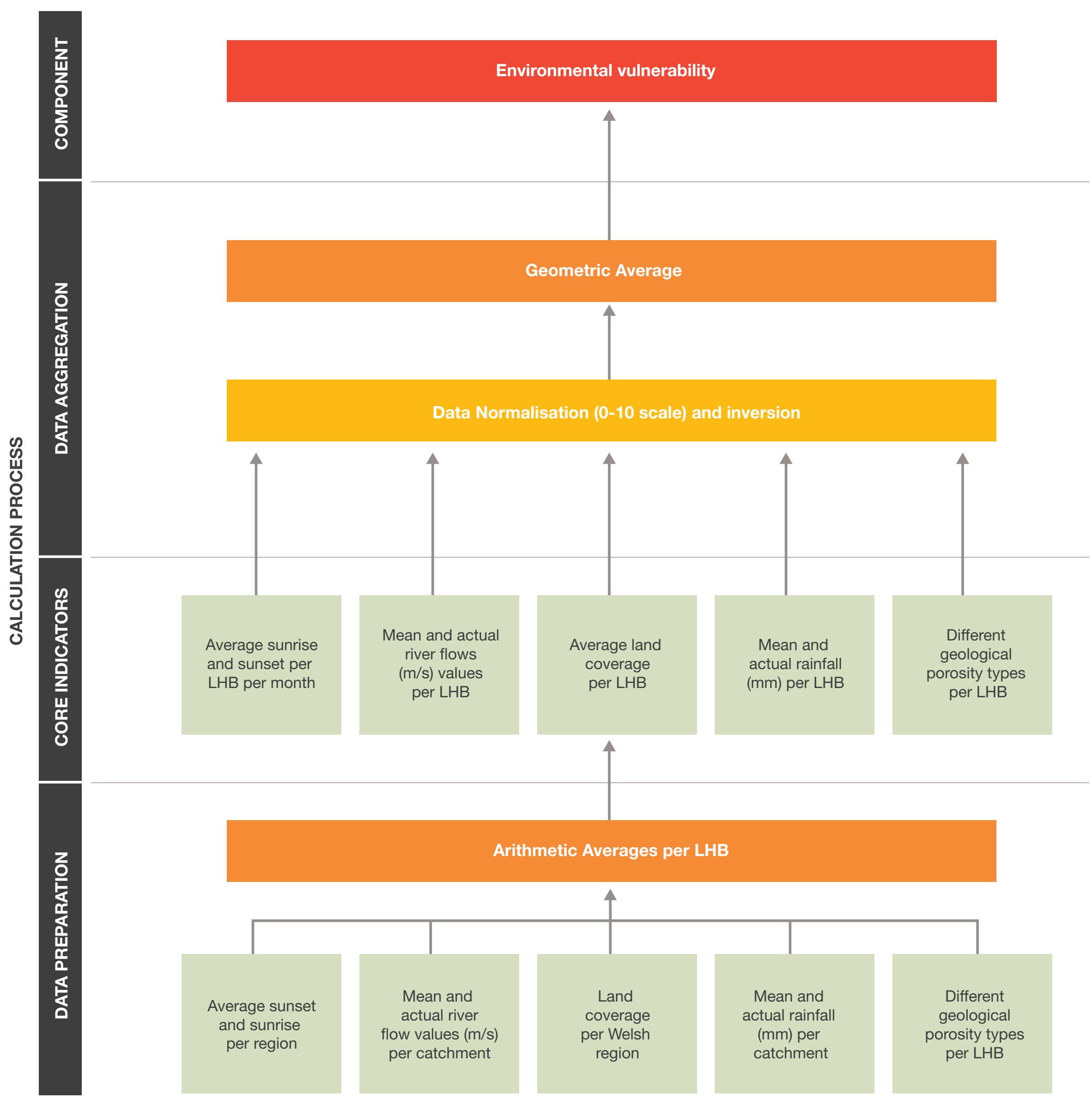

Figure 17: Natural Environment score calculation process (Author, 2025)

HEALTH & GENERAL INFRASTRUCTURAL RESILIENCE:

The main role of this aspect of the index is to indicate whether current healthcare services and general infrastructure can cope with the impact of a hazard and support the community's general mental health needs. Measuring health and general infrastructural resilience can help local and regional government and emergency services respond and provide the most appropriate services and responses adapted to the community's needs and demography (Yazdani *et al.*, 2022), reducing the impact of hazards and disasters.

CATEGORIES:

There are two subcategories within this section of the index, these are healthcare resilience which focuses on the condition of health services within the specific LHB, such as the provision of facilities and availability of healthcare workers. The general infrastructure component focuses on amenities, such as schools and community centres and providing basic services, such as electricity and mobile phone service. A geometric mean interconnects the two categories to highlight the relationship between healthcare

DEFINITION: HEALTHCARE RESILIENCE

Healthcare professionals, the number of healthcare-trained emergency services and physical healthcare services, such as GP practices and hospitals are critical during and post-hazard to prevent further deterioration in mental health and well-being of community members. All aspects of healthcare infrastructure need to be operational and accessible during and after a hazard so arithmetic mean will be calculated to reflect the importance of these factors.

Indicator	Source	Measure
Number of major trauma, Minor injury units, Community and Psychiatric hospitals per LHB	Hospitals DataMapWales (2024)	Name and type of hospital, location, and LHB
Number of GP practices per LHB	GP Surgeries: Main Sites DataMapWales (2024)	Name of GP, Location and LHB
Number of Community Pharmacies per LHB (2022–23)	Community pharmacies by LHB and year. StatsWales (2024)	Number of pharmacies per LHB
Number of GPs per LHB and 10,000 people (2023)	Fully qualified GPs (headcount and full-time equivalent) by sex and local health board StatsWales (2024)	Headcount of fully qualified GPs per LHB and per 10,000
Number of NHS Staff per LHB per speciality	Medical and dental staff by grade and year (2023) StatsWales (2024)	Headcount of staff by grade and year

Figure 18: Table of indicators for healthcare resilience

WHY WERE THESE INDICATORS SELECTED?

Firstly, they provide a strong reflection on the availability of healthcare services within a specific LHB to enable authorities to be aware of the resources available to help support and provide agency to communities to recover post-disaster (Osei-Kyei *et al.*, 2021).

This can allow the authorities to direct the healthcare resources to an area before the hazard and develop coping strategies with community leaders to help mitigate the hazard's impact on the community's mental health.

Moreover, having the healthcare indicators can show whether there are shortages of staff or facilities which would be needed in the instance of a climatic hazard, so, could help to direct funding and target interventions from either non-governmental organisations or other emergency services.

DEFINITION: GENERAL INFRASTRUCTURAL RESILIENCE

The availability of mobile phone reception and basic infrastructure, such as sanitation, is crucial to ensure the sharing of important messaging and allowing community members to either safely evacuate or be informed of the hazard and its potential impact on housing and local amenities, which could influence safe habitation of an area (Carvalho and Spataru, 2023).

Infrastructure is also vital to help aid the response of the emergency services and post-hazard recovery, if infrastructure, such as sanitation and mobile reception are severely damaged this hinders recovery and disrupts livelihoods adding extra stress, increasing the risk of individuals developing mental health conditions (Tasdik Hasan *et al.*, 2020).

All aspects of general infrastructure need to be operational and accessible during and after a hazard, to allow for recovery and reduce the risk of community members developing mental health conditions, so, the arithmetic mean will be calculated to reflect the importance of these factors. When calculating the score, three tiers of scores – no damage, 50% capacity lost and 100% capacity lost – will need to be calculated depending on the damage to core infrastructure, defined in this index as electricity access, sanitation access and access to clean water (Deelstra and Bristow, 2023).

These are the core infrastructures needed to recover from a natural hazard and if not available can increase the risk of individuals developing mental health conditions.

"... if infrastructure, such as sanitation and mobile reception are severely damaged this hinders recovery and disrupts livelihoods adding extra stress, increasing the risk of individuals developing mental health conditions."

Indicator	Source	Measure
Mobile phone reception coverage	Mobile signal strength measurement data from our spectrum assurance vehicles Ofcom (2023) UK Towns with Mobile Survey data MastData (2024)	Mobile signal strength of 5G networks across Wales Strength of 5G per provider per Welsh Town
Internet access	Percentage of unavailability of broadband at 30 mb/s WIMD Index (2019)	Percentage of unavailability of broadband at 30 mb/s per LHB
Adult Illiteracy	Adults aged 25–64 with no qualifications WIMD Index (2019)	Adults aged 25–64 with no qualifications per LHB
Clean Water availability	Determined at threshold depending on the extent the amenity is damaged	For example: 100% availability 50% availability 0% availability
Electricity availability	Determined at threshold depending on the extent the amenity is damaged	100% availability 50% availability 0% availability
Sanitation availability	Determined at threshold depending on the extent the amenity is damaged	100% availability 50% availability 0% availability
Road density and access	Road length (Km), by type of road and local authority, Wales StatsWales (2022–23)	Road length (Km), by type of road and local Authority, Wales
Number of Schools	Schools' census results: January 2023 Welsh Government (2023)	Number of schools maintained by a local Authority
Number of emergency service personnel (police and fire brigade)	Police workforce, England and Wales: 31 March 2023 (second edition) GOV.UK (2023) Fire and Rescue Service summary information by asset and financial year StatsWales (2023)	Number of Police Personnel per 100,000 people Number of fire personnel per 10,000 people

Figure 19: Table showing the indicators for general infrastructure resilience

WHY WERE THESE CATEGORIES SELECTED?

Firstly, these categories were selected as they show the ease for community members to access communication of warnings through online services so they can keep informed of how the hazard is unfolding; when to evacuate/return; and rebuild lives afterwards by accessing online services, such as banking, which could have been damaged and is critical for small businesses and communities to keep their finances in check (Eyre, De Luca and Simini, 2020). The internet is a tool which can help provide agency during a hazard, and not having it means people lose control of the situation which can increase the risk of individuals developing mental health conditions, for example, digital healthcare services provided over the internet can allow individuals to continue to receive care without their mental health condition deteriorating (Lokmic-Tomkins *et al.*, 2023). 5G had to be selected as 3G networks are disconnected by 2025 and 4G statistics are not as widely available as 5G (Clark, 2024). Furthermore, adult literacy is key as warnings are often communicated through written formats, so, if people lack the skills to understand written messaging, they are less likely to understand what is going on which in turn increases the likelihood of an individual either developing or exacerbating a current mental health condition (Engelman, Craig and Iles, 2022).

Road access and quality are important to allow people to have a better connection to communities outside of the hazard zone and allow for easier evacuation. Road connections are crucial as they enable emergency services better access to the area most affected by the hazard and bring in temporary infrastructure, such as mobile hospitals, to help with recovery efforts (Loreti *et al.*, 2022). Schools are also key infrastructure as they can be used as evacuation centres but can also be sites which can provide mental health support to communities, particularly young people by being trained in mental health first aid and providing normality to people's lives by continuing lessons etc. during the hazard event which can reduce the impact of the hazard on young people's mental health (Feinstein and Mach, 2020).

Moreover, the key indicators highlighted in red of clean water, sanitation, and electricity availability will be crucial in determining whether people will have to stay in evacuation centres and the length of stay in these centres. As these are expressed at percentage intervals, it can provide a comparison to indicate levels of resilience and the extent of impact on overall resilience. Stays in evacuation centres and the loss of basic amenities can reduce community resilience and increase the risk of mental ill health. For example, during Hurricane Katrina, predominantly African American residents were evacuated to the Superdome sports Arena. Despite the arena being designated an evacuation zone, the centre was badly damaged during the hurricane, lacked adequate supplies, such as food and drinking water (Delisi, 2006), and had poor sanitation (Guridy, 2011). Therefore, the evacuees who were evacuated to the Superdome had a higher risk of developing mental distress and vulnerability after Katrina (Grunfeld, 2006).

Finally, the number of other emergency personnel is crucial as it can show how areas can cope to support communities and aid healthcare services through their training to support people who have been in mental health crisis, for example, the police are required to be trained to support people who are experiencing mental crises to be able to section people (Marcus and Stergiopoulos, 2022).

> "Stays in evacuation centres and the loss of basic amenities can reduce community resilience and increase the risk of mental ill health."

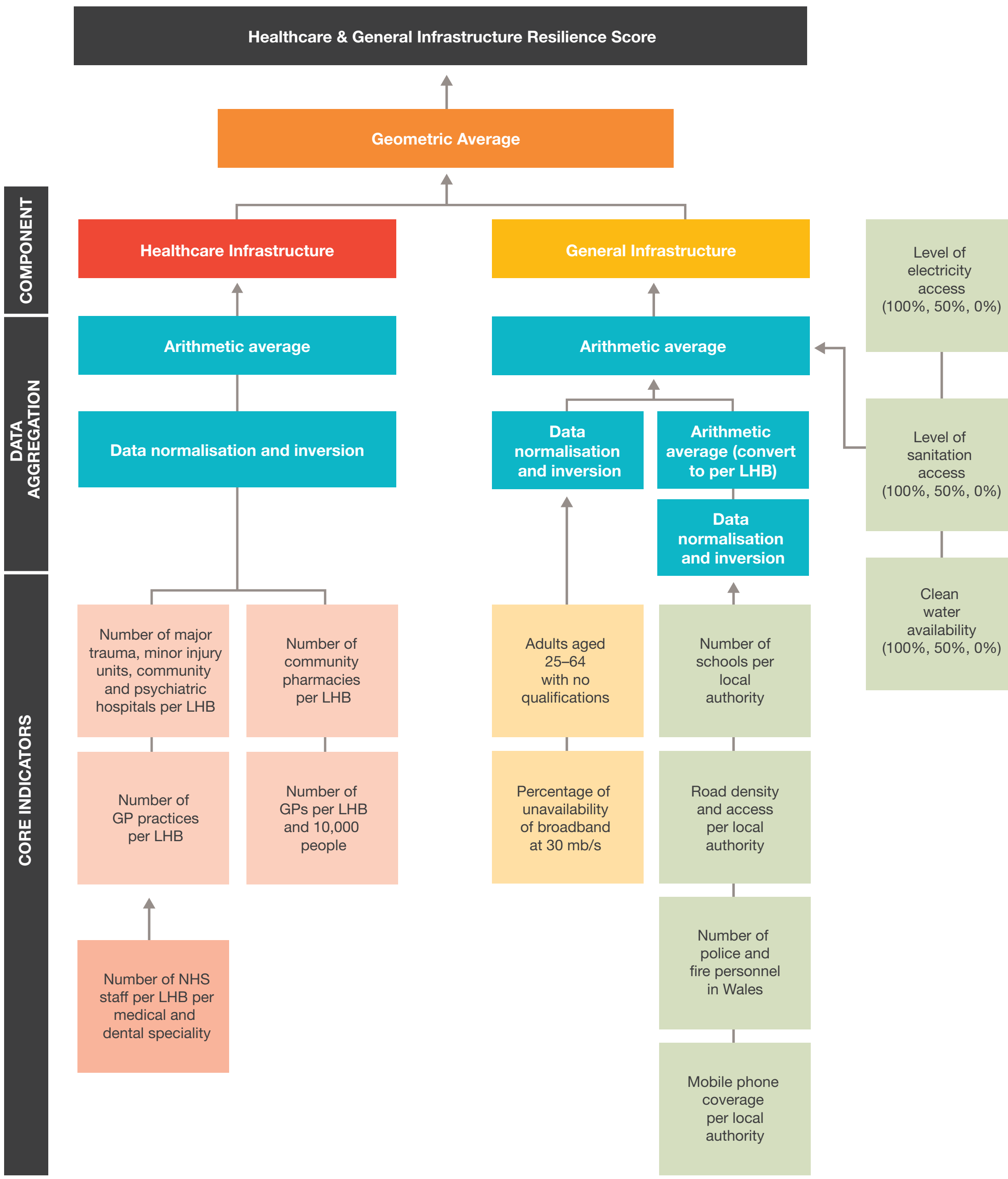

Figure 20: The calculation process for the infrastructural resilience score (Author, 2025)

Limitations of the Index

There are several limitations which will be addressed within this section due to the partial recognition of the complexity of determining mental illness risk, scalability and availability of data sources.

METHODOLOGICAL LIMITATIONS:

Simplification of reality:
The index only shows the risk on a large scale by using LHB areas, rather than considering more localised differences in risk between communities, could cause policymakers to create proposals which are not necessarily of value to all communities. The larger-scale analysis was performed because there was no healthcare and geological data available on a small enough scale to create more localised measurements. Thus, this index should complement other advice and measures from healthcare professionals and environment agencies working on a localised level, to provide more nuanced and relevant information and advice.

Interference between different components:
Despite attempts to show how changes in core infrastructure could weaken and influence general infrastructural resilience, the index does not consider the interference of different factors, such as the socio-economic vulnerability measure with the hazard and exposure measure.

Application of Proxies:
Predicting incidences of mental illness can be a complex process, and there may not be data there which measures mental illness in the exact way which was needed to create this index. Thus, proxies were applied to show the closest outcome and provide a score similar to what would be produced if the exact data were available. However, using proxies may not fully represent what needs to be shown and the lack of data hinders the production of the most accurate picture possible. For example, rather than using the percentage of illiterate adults, as this was not currently available, a proxy had to be used which ended up being the percentage of the population aged 25-64 who had no academic qualifications.

Time:
As there were only six months between conceptualising and delivering the current product, there was no time to explore more detail and alter the index to measure risk on a smaller spatial scale or apply the index to other countries in the UK. Thus, future editions of the index could expand upon this further.

DATA LIMITATIONS:

Data sources not included:
Some climate change-related hazards, such as pandemics, were not included in this index, despite their considerable impact on mental health. This exclusion occurs because no publicly available data quantifies the impact of a pandemic on mental health in a Welsh context. However, if the MHVI is applied in other countries where data proxies exist for the impacts of pandemics on mental health, the MHVI can be adapted to incorporate such proxies. Moreover, this index was designed to be used at a more localised level by communities, and all the data in the report is open access, making the index an accessible tool for monitoring the impact of hazards and ultimately providing communities with ownership over their responses to these challenges.

Simplification of data:
To ensure the data fitted the LHB boundaries, some indicators had to be averaged which prevented a more nuanced data pattern from emerging to reflect that the nature of poverty in Wales is not widespread but far more complex, which creates more complicated pictures surrounding the mental health of the nation and how communities who have high levels of mental ill health respond to climatic hazards. Thus, the index can oversimplify the challenges climate change poses to mental well-being.

Data production:
Despite the best attempts made to locate the most up-to-date data available, there are still indicators in the index which are from 5 – 6 years ago. Thus, the indicators may not create an accurate picture of the risk of a population developing a mental illness in the face of a climatic hazard.

CREATING AN INDEX:

Attempting to measure and monitor a population's risk of developing a mental health condition during a climatic hazard can be extremely complex, and this index does attempt to over-simplify this, so users such as policymakers and healthcare professionals need to be aware that there could be other external factors which have not been considered within this index.

The provision of a score which employs a ranking system has been created by applying mathematical tools in specific ways to show 'risk' through the lens of the indicator. Furthermore, as this tool is an index it only provides results for the indicators imputed into the model, which have been chosen based on their relevance to understanding mental ill health and climate change.

The index produces valuable information, such as rank between 0-10 to show how at risk a LHB is and the difference between LHBs which can show which areas are susceptible to mental illness during a climatic hazard.

> "... this index was designed to be used at a more localised level by communities, and all the data in the report is open access, making the index an accessible tool for monitoring the impact of hazards and ultimately providing communities with ownership over their responses to these challenges."

Creating a Mental Health Vulnerability model:

The following step needs to be undertaken prior to inputting data into the risk model:

RESCALING DATA USING A (0-10) SCALE:

The process of rescaling the data is performed using the min-max normalisation with the data showing that 0 is the lowest level of resilience (highest risk) and 10 is the highest level of resilience (lowest risk). To make normalisation easier, all figures are rounded to one decimal place and outliers are removed to prevent the minimum and maximum values from being very different from the rest of the data. Fixed minimum and maximum values help minimise distortion and consider what the indicator intends to show. To normalise the data to a 0-10 scale, the following equation can be used:

$$x = \frac{x_i - x_{i,\,min}}{x_{i,\,max} - x_{i,\,min}} \times 10$$

x = Normalised value

x_i = Imputed Value

$x_{i,\,min}$ = Minimum value

$x_{i,\,max}$ = Maximum value

As outliers are separate data points from the main data source and show that the data contains a high kurtosis or is heavily skewed. Therefore, outliers will need to be discarded to prevent errors when producing the index scores. To identify outliers the following can be used to identify them.

Box Plot: Using the interquartile range (IQR) marked, the data outside the lower and upper quartile points can be removed to prevent skewed data points.

DATA INVERSION:

Once the data has been screened, and normalised the methodology outlines that 0 is the best and 10 is the worst value. So, the data will need to be inverted so the higher values will produce a lower risk score on the normalised data. Here is the equation to show the process of inversion:

$$x_{inv} = 10 - x$$

x_{inv} = inverted value

x = normalised value

AGGREGATION:

The following aggregation tools have been applied within this report and outlined in the methodology:

- Arithmetic average
- Geometric average

The aggregation process works bottom-up and starts with the indicators and works up to the final calculation which is shown in Figure 2.

The application of arithmetic and geometric averages has been selected because arithmetic averages are constant whereas geometric averages provide results with higher averages and subsequently, higher mental health resilience scores. Thus, having geometric averages helps to show policymakers and healthcare professionals that improving the lower-scoring factors can help improve their overall mental health resilience score. For example, when considering the hazard and exposure section if one LHB had a high hazard score but a lower exposure score, a high score for hazard and exposure would still be produced as the population has already experienced various kinds of hazards which places them at a higher level of susceptibility to mental health conditions.

Conclusion:

The MHVI report shows the current gaps in EWS and DRR mental health research, literature and practice within the academy and beyond and outlines a novel solution, the MHVI, in the context of Wales, UK, and the Welsh health care system. The MHVI can help governments, local and public health authorities, emergency services and communities better understand the risks climate change can pose to their mental health and ensure timely interventions are implemented, to reduce the mental ill health risk. Climate change poses significant challenges to community mental health resilience, with flooding and drought events which can significantly increase the risk of anxiety (MB24.3), depression (6A7Z) and PTSD (6B40) (Morganstein and Ursano, 2020). Thus, EWS and DRR strategies must adopt anticipatory systems which can help adequately prepare a community in a timely fashion, involving long-term resilience initiatives, rather than responsive approaches which could leave community members ill-prepared, increasing mental ill health risks.

Despite there being multiple climatic hazard-based EWSs and DRR initiatives strategies, the literature review identified multiple gaps in current climatic hazard strategy, particularly in the provision of support post-hazard. Currently, there are many EWS and DRR indexes to address climatic hazards, but there has been limited consideration of mental health care within such strategies, which tend to either follow a top-down approach or if they do provide mental health care, it is often over a short-term period. This can lead to a lack of consideration for community mental health needs, leading to an increase in mental ill health risks and can perpetuate inequalities against ‘vulnerable’ groups. Therefore, it is recommended that an MHVI is created to help policymakers, emergency services and aid organisations identify communities at greater mental ill health risk, and to implement strategy before hazards happen to reduce instances of mental ill health. Furthermore, more interdisciplinary research needs to happen surrounding community agency, vulnerability and mental ill health to work in co-partnership with MHVI to develop anticipatory solutions which support communities’ needs and prevent the perpetuation of inequalities against vulnerable groups.

To resolve a knowledge gap, a novel solution, the MHVI, was developed to help governments, public health authorities, emergency services and communities in the UK to identify areas at greatest risk of developing mental ill health during climatic hazards. The MHVI is a composite index made up of five core components (socioeconomic vulnerability; hazard and exposure; population health: mental health; natural environment; health & general infrastructural resilience) and 53 different indicators to calculate overall community vulnerability. The report outlines how to calculate MHVI, using Wales, UK, and its LHB system as a case study example, with the devolved nation experiencing high levels of poor health and high vulnerability to climatic hazards (ONS, 2022; Bone, 2024). As Climate Change continues to worsen, the mental health implications of climatic hazards must be fully understood to protect communities and prevent the perpetuation of inequalities within climatic EWS and DRR infrastructure. Even though possible critiques will note the MHVI to be an arbitrary tool which makes sweeping and medicalised assumptions of overall vulnerability in communities who might not see themselves as vulnerable. However, the MHVI is not being proposed as a one-size-fits-all approach to addressing mental health vulnerability but aims to be a tool which can be used as a starting point locally, regionally and globally, to initiate discussion and raise awareness amongst decision-makers of the mental health risks of climatic hazards, and instigate more anticipatory disaster preparation to improve community resilience. Hopefully, in the future, the MHVI will evolve and be adapted to suit a greater number of cultural contexts and understandings of mental health, which will help make community mental health resilience in the face of climatic hazards more anticipatory on a global level.

> “As Climate Change continues to worsen, the mental health implications of climatic hazards must be fully understood to protect communities and prevent the perpetuation of inequalities within climatic EWS and DRR infrastructure.”

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