

In collaboration with  
L.E.K. Consulting



# Health Impacts of Climate Change: Evidence Landscape and Role of Private Sector

INSIGHT REPORT

JUNE 2024



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# Foreword



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Climate change presents an imminent and pervasive threat to human health around the world. It is already causing more climate-related deaths and worsening medical conditions including infectious diseases, chronic illnesses and mental health disorders. It is also increasing the strain on global health systems and on socio-economic factors that indirectly affect health outcomes.

According to the World Economic Forum's 2024 Global Risks Perception Survey,<sup>1</sup> extreme weather is perceived to be the top risk most likely to trigger a significant global crisis over the next decade, with almost all other environmental risks also ranking among the top 10 long-term threats.<sup>2</sup> Certain populations, particularly those in climate-exposed areas and reliant on natural resources, face compounded risks due to limited financial resources and simultaneous burdens of conflict and institutional fragility. However, they often receive comparatively less international assistance.<sup>3</sup>

Given the cascading effects of climate change, failure to address it could condemn millions to poverty, exacerbate fragility and conflict, and irrevocably alter the fabric of our societies.<sup>5</sup>

Engagement and concerted actions across sectors are imperative to forge a path towards building climate-resilient health systems. These must take a holistic approach that encompasses building resilience, enabling agile response and supporting long-term recovery.

However, as the Global Risks survey 2024 also revealed, key decision-makers regard the

urgency of environmental risks differently. While civil society and governments view these risks as impending priorities, the private sector primarily views them as longer-term concerns, despite its own indispensable role in the collaborative effort to safeguard human health against climate change. In addition, with substantial business interests and well-being of employees at stake, businesses can no longer afford to overlook this issue.

The World Economic Forum's Climate and Health Initiative, through multistakeholder collaboration and cross-sector partnerships, aims to drive systemic transformation for improved climate change adaptation strategies to strengthen societal health and resilience. In collaboration with L.E.K. Consulting and based on a robust review of existing research on health areas affected by climate change, this report aims to identify the key gaps in guidance, pinpoint areas requiring immediate action and recommend interventions where the private sector can play a significant role.

This report serves as a catalyst for meaningful dialogue, guiding strategic investments and tangible actions to help build a future where healthcare systems and communities stand resilient in the face of environmental challenges, all while ensuring that vulnerable populations are at the centre of these responses. With the threat posed by climate change already visible and ever-increasing, stakeholders across sectors and around the world must stand united in their commitment to protect the health and well-being of current and future generations from its impacts.



**Countries that are fragile and in conflict-affected settings are the ones that bear the biggest brunt of climate change.**

Anna Bjerde,  
Managing Director  
for Operations,  
World Bank<sup>4</sup>

# Executive summary

The impact of climate change on public health presents critical risks that demand urgent attention. Vulnerable populations – such as low-income communities, populations residing in natural disaster-prone areas, women, children and the elderly, in particular – bear a disproportionate burden of such health risks with insufficient support for mitigation and recovery. It is crucial to acknowledge the interconnectedness of environmental changes and public health. Human health needs to be factored in climate and nature initiatives, as well as movements for effective climate action. This is essential to foster resilience within communities and mitigate the adverse health effects of climate change.

While the visible impacts of climate change on weather patterns are widely acknowledged, there remains a need for greater understanding of its health effects and the corresponding actions that different stakeholders can take to mitigate these impacts. This report aims to pinpoint the climate-health intersections most in need of immediate attention, and offers guidance for intervention by the private sector, the public sector and non-profit organizations.

This report focuses on four main manifestations of climate change:

- **Extreme weather:** Extreme weather events affect approximately 189 million people annually, with developing countries experiencing 79% of recorded deaths and 97% of the total recorded number of people affected since 1991.<sup>6</sup>
- **Air quality:** Air pollution causes 6.7 million premature deaths globally every year and disproportionately affects urban populations due to indoor air pollution, which is a major contributor to overall air pollution. Nearly 91% of premature deaths related to air pollution occur in low- and middle-income countries (LMICs), particularly in South-East Asia and the Western Pacific Region (as designated by the World Health Organization).<sup>7</sup>
- **Food and water risks:** Food insecurity affects 2.3 billion people globally,<sup>8</sup> particularly in low-income countries where 60% of the population is affected;<sup>9</sup> 2 billion people around the world lack access to clean water, which affects low-income communities most severely.<sup>10</sup>

- **Infectious agents:** Nearly 14 million deaths globally per year are infection-related,<sup>11</sup> and over half of all infectious diseases are aggravated by climate change.<sup>12</sup>

These climate change manifestations have diverse health impacts, with more severe and enduring effects in some areas than others.

The assessment includes direct impact on health outcomes across different disease areas, as well as indirect impact on the broader social, economic and healthcare factors that have a bearing on health.

The assessment of the intersections between climate change and health helped identify 195 high-impact intersections – where climate change has the biggest impact on health both directly and indirectly. Extreme weather, and food and water risks, were found to have the most widespread and severe health impact compared to other climate change manifestations. Specifically, food and water risks displayed the most extensive direct health impact, while extreme weather and infectious agents showed the most extensive indirect health impact.

Despite growing awareness that climate change threatens health, the availability of research efforts to better understand these intersections varies considerably between different climate change manifestations and related phenomena (called “sub-themes” in this report), as well as their health effects, as does the availability of actionable guidance to address these impacts.

To prioritize the areas most in need of intervention, the team behind this report carried out a comprehensive review of academic studies and reports to identify areas where research and actionable guidance fall short. The team identified 13,000 unique publications by scraping the web<sup>13</sup> and found 39,000 matches with the areas where climate change has a high impact on health.

Further, the team identified 22 priority topics spanning 10 health areas. These health areas are significantly affected by a range of climate change manifestations,<sup>14</sup> and are designated either as “hot topics”, i.e. those receiving the most actionable guidance at present, or “lagging topics”, i.e. under-researched intersections that lack actionable guidance.

The 10 health areas are listed below. Some of these are a mix of both “hot” and “lagging” topics.

**Priority direct health areas:**

- immune system/infectious diseases (“hot”)
- nutritional and metabolic diseases (“hot”)
- neurodevelopment/mental health (“hot”)
- cardiovascular system (“hot” and “lagging”)
- respiratory system (“hot” and “lagging”)
- pregnancy (“lagging”)
- digestive system (“lagging”)

**Priority indirect health impact areas:**

- social inequality (“hot”)
- displacement and migration (“lagging”)
- health system and infrastructure disruption (“lagging”)

The systemic drivers identified were a result of climate change or of pre-existing factors. The most common of these drivers are: infrastructural damage or disruption; change in agricultural conditions; change in vector ecology; increased proliferation of contaminants; livelihood disruption and financial loss; health services constraints or access challenges; lack of infrastructure and resources; and gaps in scientific knowledge.

Given that many downstream health effects arise from several drivers acting together, interventions directed at addressing these common drivers hold the greatest promise for achieving widespread and effective mitigation of the health impacts of climate change. This report identifies six critical areas for intervention:

- Early warning systems
- Healthcare access expansion and equity
- Critical infrastructure and supply chain resilience
- Agricultural resilience
- Access to financial risk management
- Scientific research

These areas are ripe for private sector involvement. Engaging private sector stakeholders across industries enables the development of cutting-edge technologies, efficient delivery of interventions and mobilization of financial resources.

Clearly, action to enhance resilience and improve health outcomes extends beyond the healthcare and life sciences industry. The agriculture, construction, energy and transportation sectors also play pivotal roles due to their susceptibility to the effects of climate change and their critical contributions to economies and public infrastructure. The technology and financial sectors can contribute by providing tools and solutions crucial to enhancing the reach and effectiveness of interventions.

A holistic approach towards building resilience, enabling agile response and supporting long-term recovery is crucial for addressing all health effects of climate change. To bring together financial resources with scientific, policy, community and infrastructure stakeholders is of paramount importance, along with ensuring that the private sector, public sector and non-governmental organizations (NGOs) work together.

By harnessing the unique resources, expertise and perspectives of each sector, collaboration can unlock synergies, promote inclusivity and maximize the effectiveness and sustainability of initiatives aimed at safeguarding public health in the face of escalating climate challenges.



# Introduction:

# Climate change and human health

The impact of climate change on health manifests through different phenomena and drivers.

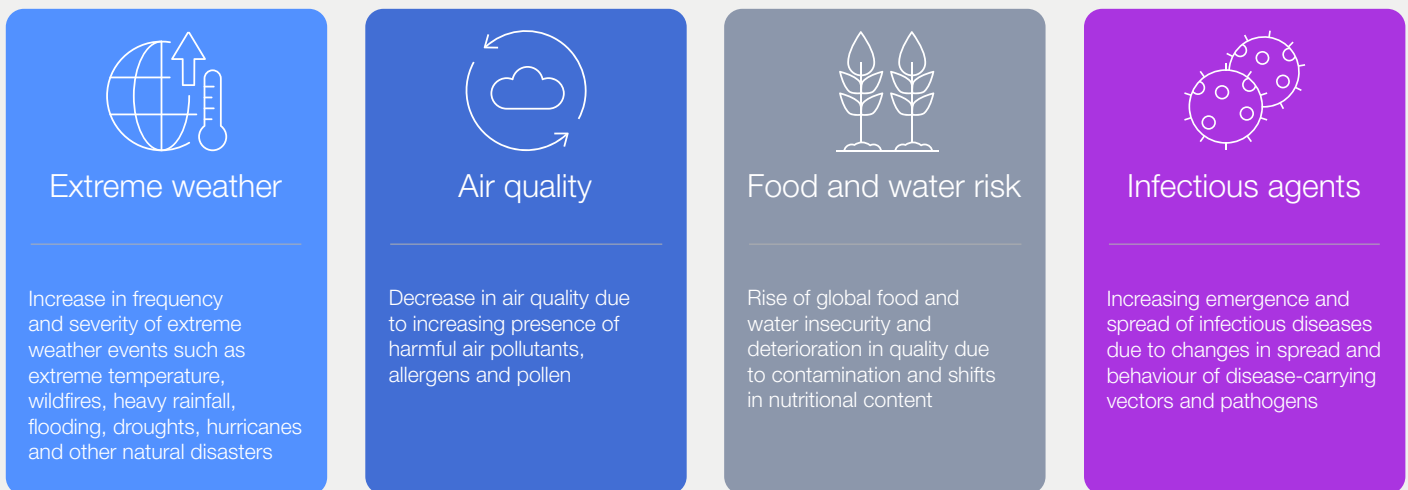
## Defining the manifestations of climate change

Climate change influences public health through its physical effects on natural, climatic and ecological conditions. These changes pose different risks to health, necessitating the need to better define the manifestations of climate change that affect health.

Based on frameworks established by leading climate change organizations,<sup>15</sup> this report defines

four overarching climate change manifestations (see Figure 1). It uses a largely consistent set of climate change-related natural hazards, as outlined by these frameworks, to define the fallouts of each of the four main manifestations of climate change. This provides a more detailed characterization of the effects of climate change and serves as a guide for subsequent assessments.

FIGURE 1 Climate change manifestations



Source: L.E.K. Consulting, World Economic Forum



## Extreme weather

Extreme weather is defined as unexpected, unusual, unpredictably severe or unseasonal weather, according to the United Nations (UN) Environment Programme.<sup>16</sup> It includes heavy rainfall and flooding, droughts, heatwaves, wildfires, storms, as well as geological hazards such as earthquakes and tsunamis. While these events occur due to natural climate variability, climate change alters their frequency, intensity, spatial extent, duration and timing. This can be attributed directly to increased greenhouse gases (GHGs) in the atmosphere, or its results such as rising temperatures, shifting precipitation patterns, glacier melting, soil erosion, ocean acidification and rising sea levels. Human activities also amplify the likelihood of simultaneous extreme events, such as heatwaves alongside droughts.<sup>17</sup>

Between 2000 and 2019, extreme weather events are estimated to have caused 1.2 million deaths and affected over 4 billion people.<sup>18</sup> Extreme weather events occur across the globe, but the scale of the impact varies by region. For example, from mid-2020 to early 2023, India faced severe droughts, while China experienced significant flooding and heatwaves.<sup>19</sup>

On average, over 130 million people worldwide are affected by natural disasters annually.<sup>20</sup> The increased frequency and intensity of extreme

weather events disproportionately affects vulnerable populations, including children, pregnant women, older adults, outdoor workers, individuals with disabilities or pre-existing health conditions, and coastal populations. Among the top 25 most climate-vulnerable countries, 19 are fragile and/or conflict affected, underscoring the alarming interplay of conflict, violence and fragility to growing climate and disaster risks.<sup>21</sup>

In addition, extreme weather events also contribute to the proliferation of microbial and chemical contaminants, both directly and indirectly. Heavy rainfall, flooding and storms exacerbate run-off of fertilizers and pesticides, leading to toxic algal blooms that endanger aquatic life and human and animal health if contaminated water is consumed.

Moreover, rising air and water temperatures can fuel the growth of water- and food-borne pathogens. Linked to these risks, flooding, storms and hurricanes can disrupt sewage and wastewater disposal systems, further amplifying the spread of waterborne pathogens. Additionally, wildfires have the potential to transform naturally occurring soil metals into cancer-causing airborne particles, compounding the health hazards posed by such events.<sup>22</sup>



## Air quality

Air pollutants and GHGs often come from similar sources, such as combustion of fossil fuels, coal-fired power plants and diesel-fuelled vehicles. Worsening air quality occurs due to higher concentrations of air pollutants, such as carbon monoxide (CO), sulphur oxides (SO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>) and ozone (O<sub>3</sub>), as well as allergens and pollen. Combustion of fossil fuels and agricultural activities represent the main sources of air pollution.<sup>23</sup>

Short-lived climate pollutants such as black carbon, methane, tropospheric ozone and hydrofluorocarbons (HFCs) are the most important contributors to anthropogenic global warming after carbon dioxide (CO<sub>2</sub>), responsible for up to 45% of current global warming.<sup>24</sup> In addition, particle pollution is associated with a wide range of health effects. These particles are emitted directly (primary) or formed from other pollutant gases (secondary) produced from combustion of carbon-based fuels.<sup>25</sup> Wildfires, a key primary source of fine particles, are increasing due to climate change.<sup>26</sup>

Warmer temperatures and rising CO<sub>2</sub> levels lengthen the pollen season, increase pollen concentration and allergenicity, and drive geographical expansion of plant species that produce allergenic pollen.<sup>27</sup> Changes in humidity and thunderstorms further exacerbate pollen concentration in the air. It is estimated that one in four people suffer from pollen-related allergies, and severe symptoms can include shortness of breath and swelling of the airways. In Europe, the costs associated with treatment and missed workdays from severe reactions can add up to €150 billion (\$1.62 billion) each year.<sup>28</sup>

Ambient (outdoor) and household (indoor) air pollution causes 6.7 million premature deaths a year worldwide collectively, 91% of these in LMICs. In particular, due to its ability to penetrate much deeper parts of the lungs, fine particulate matter (PM<sub>2.5</sub>) is driving the most significant health problems and premature mortality, with clear association to increased mortality from cardiovascular disease, respiratory disease and lung cancer.<sup>29</sup> Pregnant and non-pregnant women,

children, the elderly, people with chronic conditions, people with low socio-economic status and people of colour are particularly vulnerable to particle pollution.

For instance, due to higher exposure to polluting fuels and technologies at home, household air pollution causes more than 237,000 deaths

of children under the age of five. In developed countries, the likelihood of poor air quality is higher in major urbanized and industrial areas. For instance, over 96% of Europe's urban population is exposed to air with fine particulate matter above the guidelines set by the World Health Organization (WHO).<sup>30</sup>



## Food and water risks

Climate change presents a multifaceted, complex challenge to the availability and quality of food and water. In addition to direct effects on water availability, it also affects food availability and increases contamination risks through changes in temperature, precipitation patterns and soil microbe composition, and also as a consequence of other climate change manifestations, most notably extreme weather.<sup>31</sup>

These variables have profound implications on agricultural requirements, crop yield and nutritional quality. They also affect the risk and rate of contaminant proliferation, thereby threatening access, both economically and physically, to clean drinking water, sanitation and food.<sup>32</sup>

Freshwater availability and water stress are affected by disruptions to the water cycle, including altered precipitation patterns, accelerated glacier melting, rising temperatures and salinization of groundwater due to rising sea levels. According to the UN, terrestrial water storage has declined by about 1 cm annually over the last two decades. As a result, an estimated 2 billion people lack access to safe drinking water and approximately 50% of the global population faces severe water scarcity for at least part of the year.<sup>33</sup>

Floods and droughts exacerbate these challenges by increasing the risk of water contamination. This can occur due to the proliferation of waterborne pathogens resulting from the disruption of sewage and wastewater systems and stagnant water acting as breeding ground for vector-borne diseases. Sanitation issues, compounded by inadequate clean water supply, further heighten the risk of water contamination and the spread of infectious diseases. The United Nations Children's Fund (UNICEF) reports that 3,000 to 4,000 people die from diseases linked to inadequate water and sanitation every day, with approximately one-quarter of these deaths occurring among children under the age of five.<sup>34</sup>

The climate consequences of water extend to food security, safety and nutritional diversity. Reduced agricultural productivity results from increased pest infestation, adverse crop growth conditions, direct damage from extreme climate events and the ripple effects of heightened water scarcity. In 2021, approximately 2.3 billion people faced moderate to severe food insecurity.<sup>35</sup>



## Infectious agents

Climate change alters the global distribution of pathogens, increasing the risk of a wide range of infectious diseases, including vector-borne, waterborne, food-borne, airborne and direct-contact diseases. For vector-borne diseases, the shift is fuelled by rising air and water temperatures and changes in precipitation patterns and humidity levels, which create environmental conditions conducive to vector growth, survival and transmission.<sup>36</sup>

According to the WHO, vector-borne diseases cause 700,000 deaths annually and this number may continue to increase if preventive action is not taken.<sup>37</sup> One study has projected that disease-carrying mosquitoes could reach an additional 500 million people by 2050,<sup>38</sup> amplifying the threat of

malaria, dengue and chikungunya. Another study has projected that warming temperatures could expose over 1.3 billion new individuals to Zika virus by 2050.<sup>39</sup>

Additionally, the risk of infection may also be exacerbated by other climate-related impacts on health, such as the weakening of the immune system due to air pollution and malnutrition due to food insecurity.<sup>40</sup>

Moreover, extreme weather occurrences can escalate these risks, triggering sudden spikes in specific vector-borne diseases. For instance, severe flooding in Pakistan in 2022 resulted in a five-fold surge in malaria cases within the country.<sup>41</sup>



Natural disasters such as heavy rainfall and flooding can compromise critical infrastructure and worsen run-off, leading to the transmission of a wide range of infectious pathogens such as noroviruses, cholera and typhoid.<sup>42</sup>

While not directly caused by climate change, waterborne, food-borne, airborne and direct-contact pathogens can spread more rapidly due to warming temperatures and other changing ecological conditions. For example, air pollution particles act as vehicles for viral transmission,

with a 1 microgram per cubic metre increase in fine particulate pollution corresponding to a 15% increase in COVID-19 deaths.<sup>43</sup> In a 2022 review, climate change exacerbated 58% (218 out of 375) of infectious diseases studied.

Changes in farming practices also play a key role, for example with poor-quality irrigation water due to water scarcity contributing to the spread of food-borne and waterborne diseases, and intensified indoor livestock breeding heightening risks of zoonotic pathogen transmission.<sup>44</sup>

## The link between climate change and health

Humans are exposed to the manifestations of climate change through a variety of channels, ultimately leading to a range of health impacts. Apart from directly causing health problems, the far-reaching effects of climate change on ecosystems, economies, infrastructure and social dynamics can also indirectly affect health.<sup>45</sup>

The health impact of climate change is intricately shaped by environmental, socio-economic, behavioural and personal factors, contributing to variations in health outcomes between individuals. For instance, individuals with lower income, who have limited access to loans or insurance and/or whose livelihoods are heavily dependent on agriculture, are less likely to have the resources to mitigate health risks and may not be able to afford treatment.<sup>46</sup>

Moreover, these demographics often reside in areas geographically more prone to natural disasters and in lower income countries with less developed public infrastructure and policies. According to the Global Assessment Report on Disaster Risk Reduction in 2022, on average every year, LMICs lose 0.8% to 1% of their national GDP (gross domestic product) to disasters, whereas high- and upper middle-income countries lose 0.1% and 0.3%, respectively.

Subsequent sections of this report will pinpoint the climate-health intersections most in need of immediate attention, and then offer guidance on the interventions necessary (see Figure 2).

FIGURE 2 Analysis approach



1

# Climate-health intersections most in need of immediate attention

Prioritizing health impact areas where climate change has more long-term or severe impact, and which lack actionable guidance, is a key step towards impactful and effective action.

The extent to which climate change directly and indirectly impacts health varies substantially across health areas, as does the availability of actionable guidance to address these impacts. The need to identify and prioritize areas for targeted mitigation efforts is critical to ensure efficient allocation of resources and effective implementation of interventions.

This report presents a comprehensive framework to systematically identify intersections between climate change and health, focusing on areas where the impact is most pronounced.



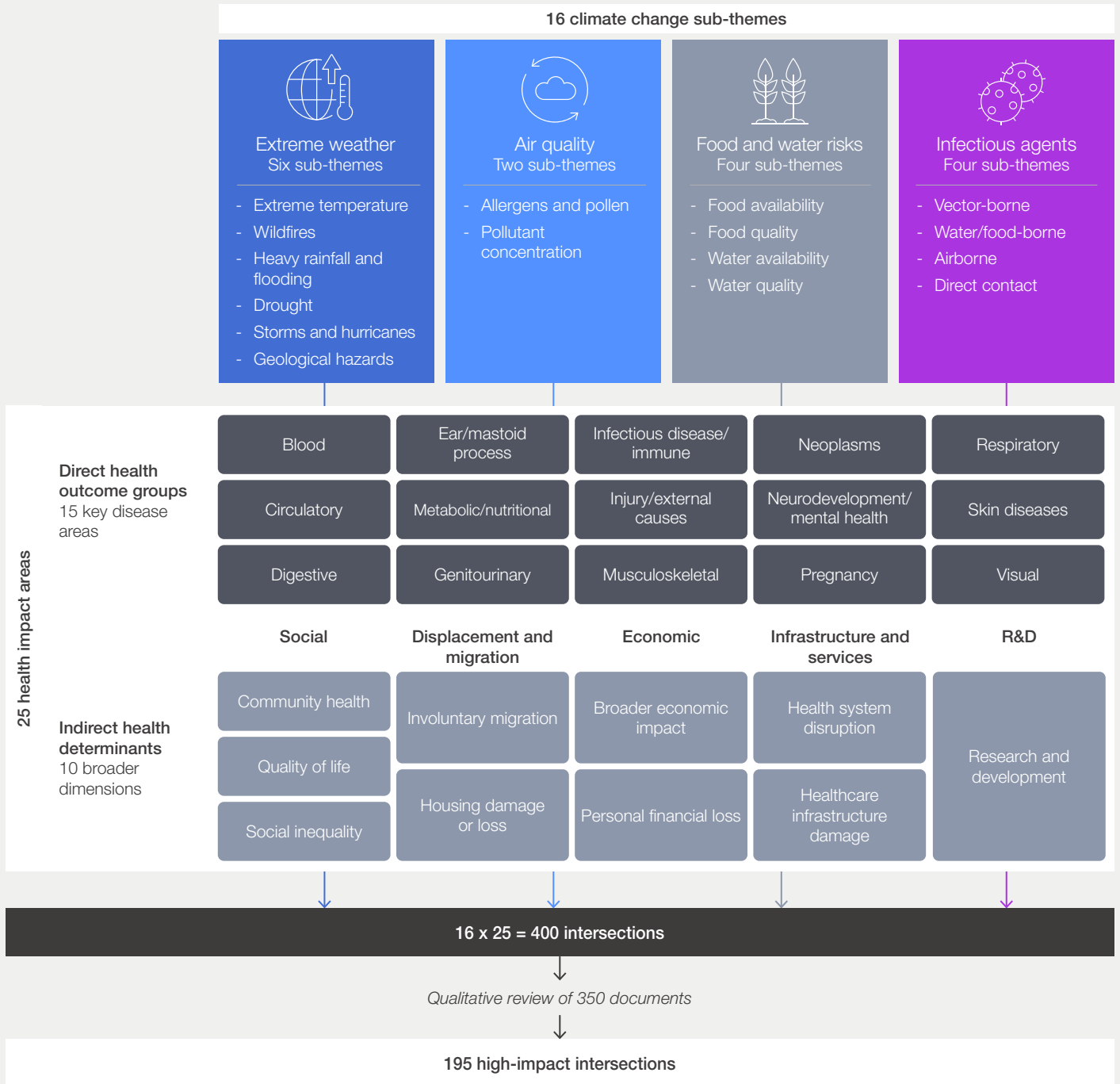
# 1.1 Assessing the health impacts of climate change

The team behind this report developed a framework to categorize the impact of climate change on health across the four main manifestations of climate change.

This framework took into consideration climate change's direct impact on health outcomes in

specific disease areas<sup>47</sup> as well as its indirect health impact through socio-economic factors that act as health determinants.<sup>48</sup> For each intersection in the framework, the evaluation of impact considered both the likelihood of occurrence and the severity of the impact.<sup>49</sup> The overall approach is summarized in Figure 3.

FIGURE 3 Approach to assessing the impact of climate change on health



Source: L.E.K. Consulting



Of the 400 climate-health intersections, the analysis yielded 195 high-impact intersections where climate change is more likely to cause harm with severe health consequences (see Figure 4).

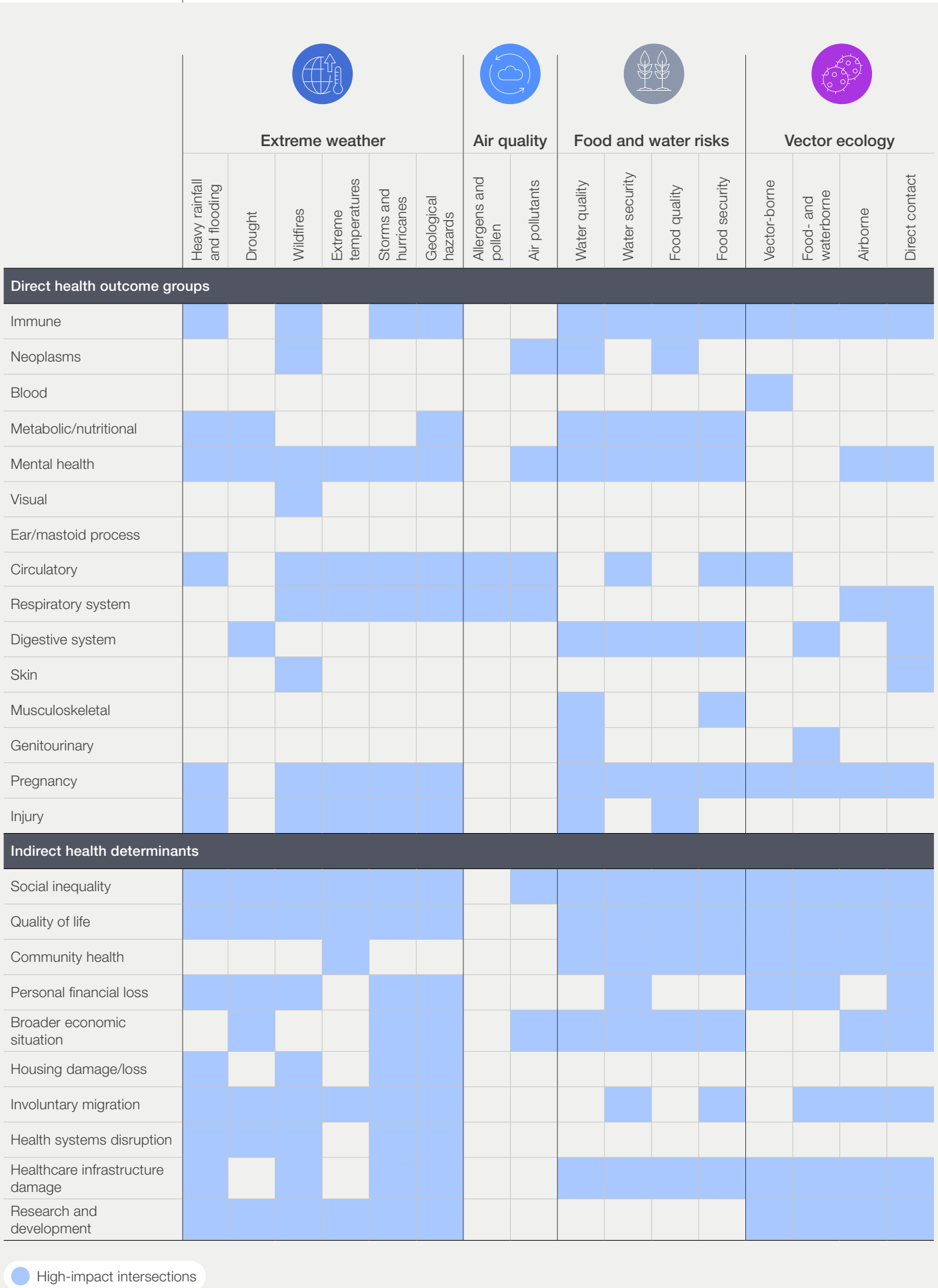
Overall, extreme weather and food and water risks have the highest proportion of high-impact intersections, indicating more widespread and severe impact on health than other climate change manifestations. Specifically, food and water risks have the most extensive direct health impact, while extreme weather and infectious agents have the most extensive indirect health impact.

The significant physical damage typically caused by extreme weather events, which can cause severe physical injury and impair affordability of or access to healthcare services, is a primary driver

for its extensive overall and indirect impact. Food and water risks, on the other hand, have the most widespread direct health consequences due to the nature of food and water as fundamental necessities for sustaining life – the contamination or inadequacy of which can affect a wide range of essential bodily functions such as metabolism and immunity.

Similar to extreme weather events, infectious agents' tendency to drive a rapid increase in demand for healthcare services and to disable societal functioning are key contributors to their extensive indirect impact. More in-depth analysis of the underlying drivers involved in specific intersections will be discussed in later parts of the report in the context of priority areas.

FIGURE 4 | Distribution of high-impact intersections



■ High-impact intersections

Source: L.E.K. Consulting

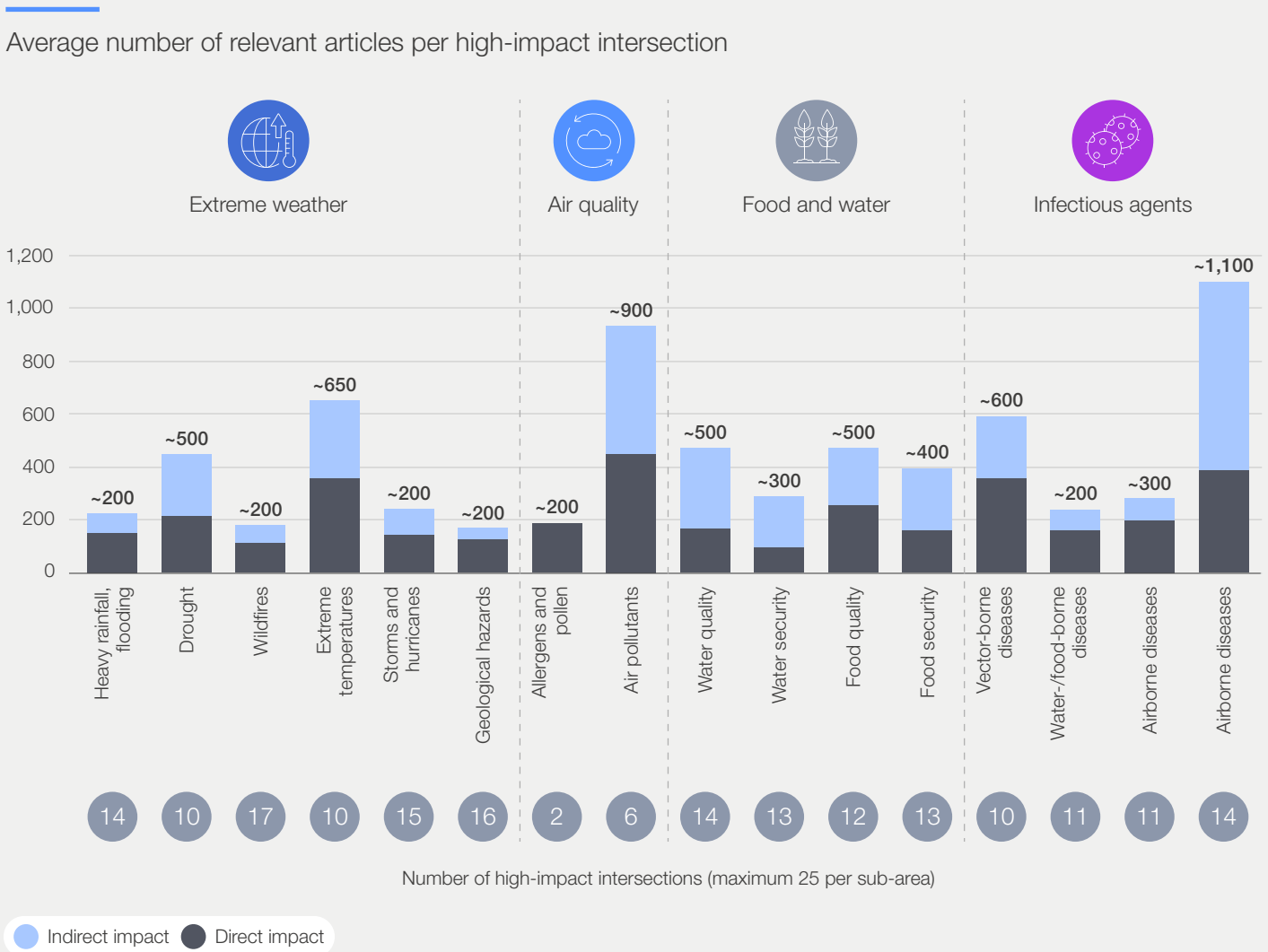
## 1.2 Assessing available evidence and guidance

The team carried out an analysis to compare variance in the research and guidance available for addressing the health impacts of climate change, and assess where the gaps lie.

Scraping the web for publicly available, English-language, climate and health resources published from 2018 to 2023, including academic literature and publications from credible organizations active in the climate and health space,<sup>50</sup> the team gathered 13,000 unique articles. These yielded 39,000 matches with high-impact intersections (one article could match with multiple high-impact intersections; see Figure 5).

Despite notching the highest number of high-impact intersections, wildfires, storms and hurricanes, and geological hazards had a below-average number of matches – displaying a disparity between their health impact significance and the amount of available research and guidance. This highlights a notable skew in global research attention towards key focal points such as direct-contact diseases (possibly due to global efforts towards the COVID-19 pandemic) and air pollutant concentrations (due to their central role in the greenhouse effect and climate change), while potentially neglecting other climate change topics with equally significant impacts on health.

FIGURE 5 Research available for each climate change manifestation sub-theme



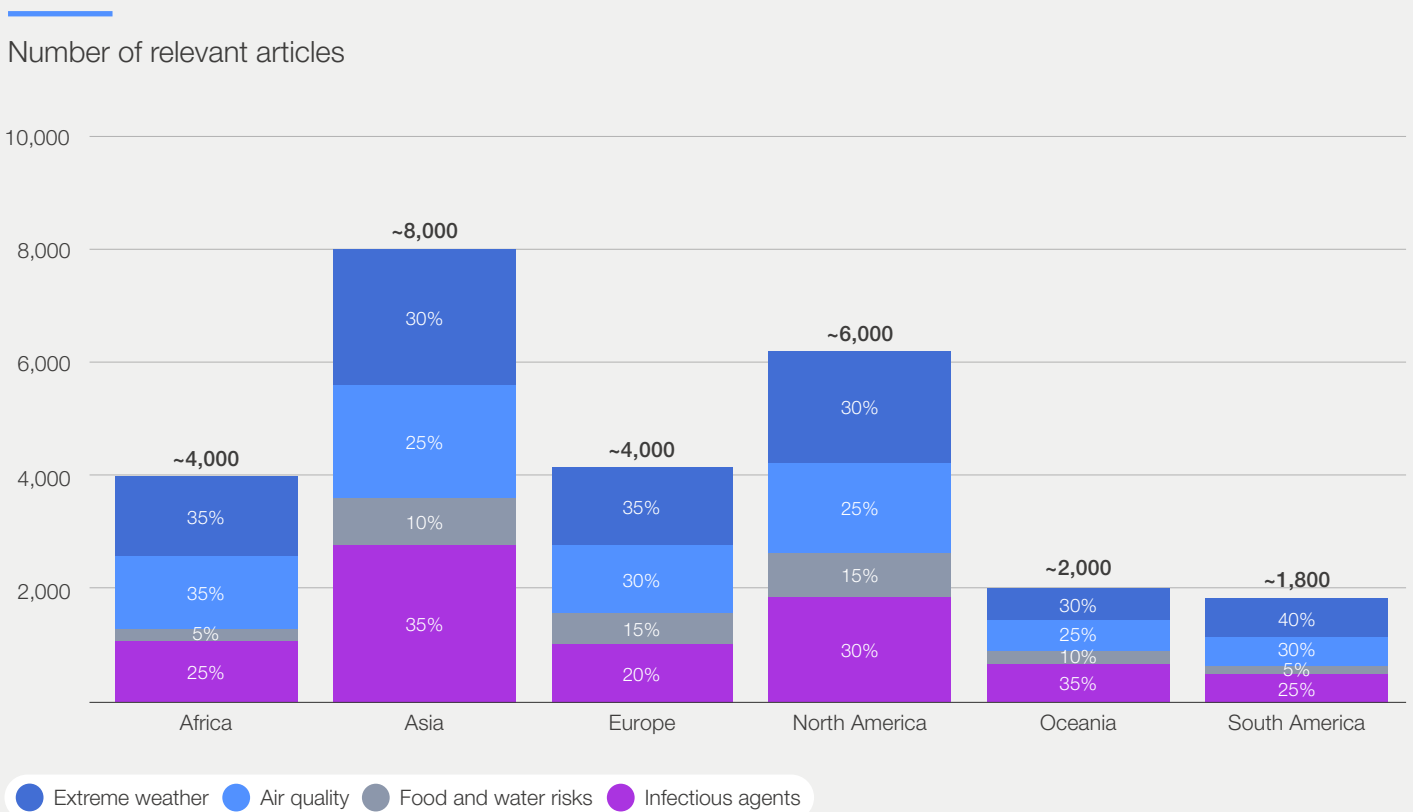
**Note:** Evidence that covers multiple climate change sub-themes or both direct health and indirect health impact areas is double-counted.

**Source:** L.E.K. Consulting

**Geographical distribution:** As shown in Figure 6, most available evidence is for Asia and North America, while available evidence is lowest for South America. This is in contrast to the level of climate risk: based on the Germanwatch Global Climate Risk Index 2021,<sup>51</sup> 50% of South American countries, 38% of Asian countries and 29% of African countries rank within the top quartile of countries most affected by climate

risk.<sup>52</sup> Conversely, less than 15% of countries in North America, Europe and Oceania fall within the top quartile. These findings suggest that current research efforts are not adequately focused on countries facing the highest climate risks, particularly in South America and Africa, indicating a critical need for additional targeted research in these regions.

FIGURE 6 Geographical distribution of available evidence



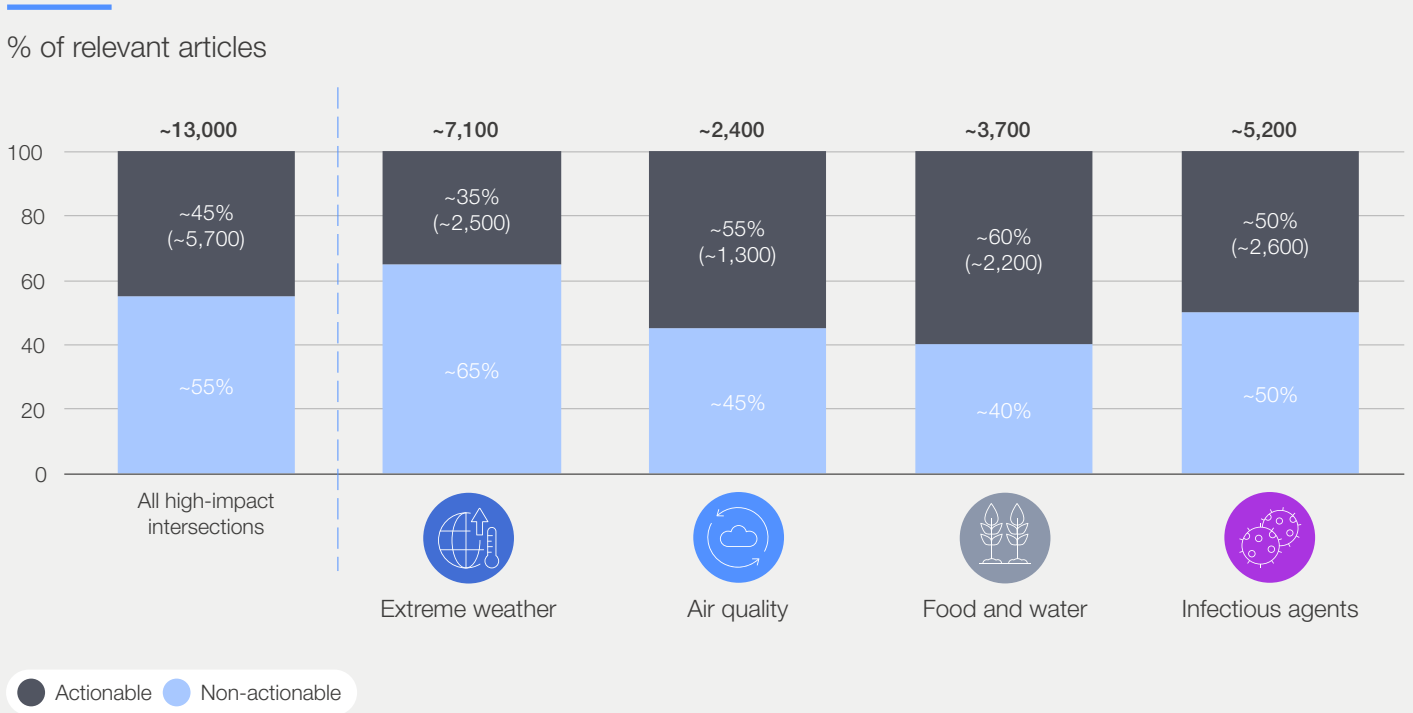
**Note:** Evidence that had matches with multiple regions or climate change manifestations is double-counted; Armenia, Azerbaijan, Cyprus, Georgia and Turkey are classified as Asian countries by the United Nations Statistics Division.

**Source:** L.E.K. Consulting

**Availability of actionable guidance:** Some 5,700 of the 13,000 articles identified contained actionable guidance on mitigation or adaptation (see Figure 7). Nearly 50-60% of the identified articles on air quality, food and water risks, and infectious agents contained actionable guidance. In contrast, actionable guidance was notably lacking for extreme weather, with only 35% of identified articles containing such guidance. Considering that extreme weather had the highest impact on health, particularly in terms of indirect factors such as quality of life or personal financial loss, the gap in actionable guidance is notable.

**Target stakeholders for actionable guidance:** As many as 3,200 (56% of 5,700) articles provided actionable guidance to the private or public sectors or both (see Figure 8). For air quality, food and water risks, and infectious agents, some 37% of evidence catered to both sectors, with 22% tailored specifically to the private sector. In contrast, evidence for extreme weather was more sector-agnostic, indicating a need for additional evidence to facilitate sector-specific actions. Overall, the availability of guidance for both the private and public sectors highlights the importance of collaboration in addressing climate-related health risks, while there is also ample evidence to support the private sector to act independently.

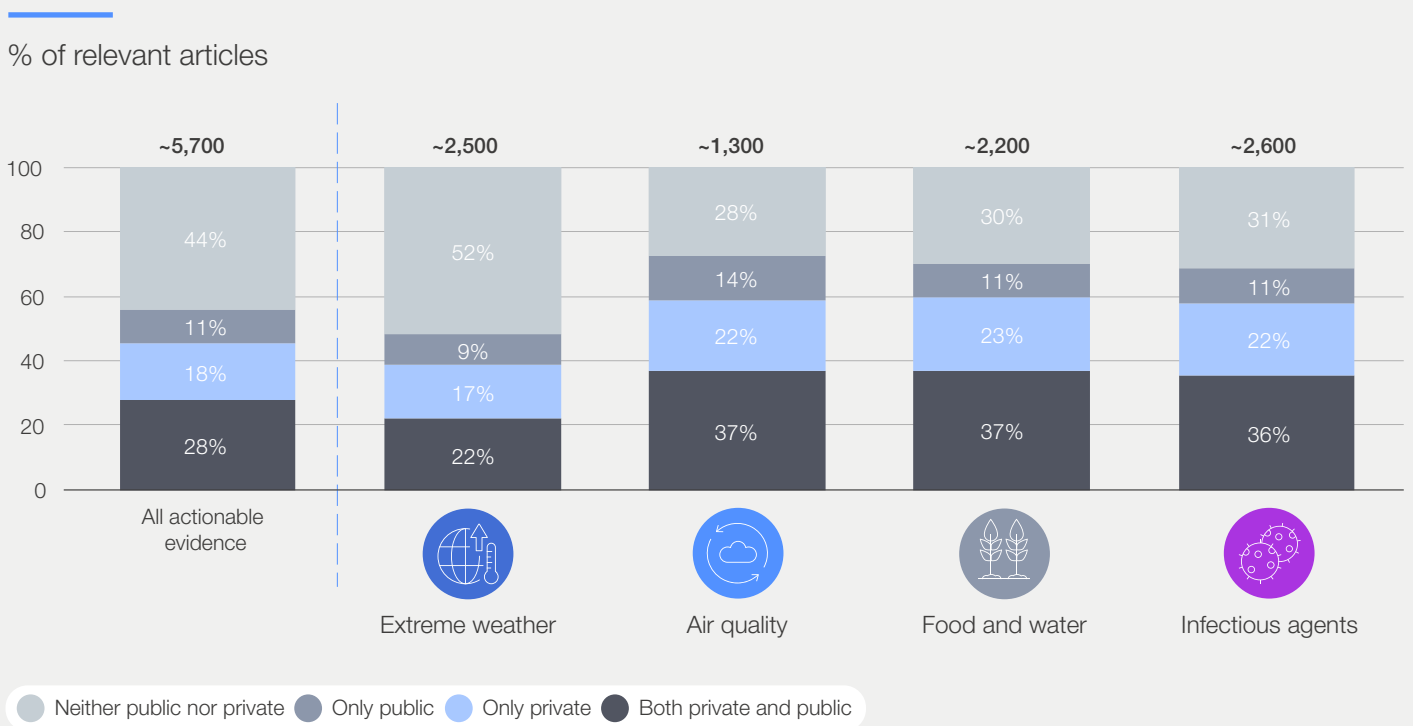
FIGURE 7 | Availability of actionable guidance by climate change manifestation



**Note:** Evidence that is relevant to multiple climate change manifestations is double-counted.

**Source:** L.E.K. Consulting

FIGURE 8 | Target stakeholder of evidence containing actionable guidance



**Note:** Evidence that is relevant to multiple climate change manifestations is double-counted in the four bars on the right of the chart.

**Source:** L.E.K. Consulting





## 1.3 Priority health areas for intervention

As the global community grapples with the increasingly urgent need for solutions to mitigate and adapt to climate change, it is imperative for stakeholders, including the private sector, to strategically allocate resources towards impactful initiatives. This report prioritizes and narrows the focus on a select range of target areas for the private sector to streamline its efforts, allocate resources efficiently and drive meaningful impact at scale.

The analysis across all 25 health impact areas aims to provide an overarching view of what current research is most focused on and to inform future research directions. However, some of these areas may not be best suited as focus areas for intervention by the private sector and have therefore been excluded from the priority topic selection process:

- **Quality of life (QoL):** QoL is a result of a complex network of factors. Health-related QoL (HRQoL), in particular, is influenced by external factors such as disease, injury, healthcare and policy.<sup>53</sup> As a result, intersections of climate change and health as related to QoL have not been considered as priority topics since the resolution of QoL concerns requires addressing other high-impact intersections that represent the upstream causes of reduced QoL.
- **Community health:** There is emerging evidence that climate change can have a significant influence on crime and violence, such as increased levels of domestic violence during an outbreak of direct-contact diseases,<sup>54</sup> and increasing rates of violence associated with increase in temperatures.<sup>55</sup> However, the intersection of climate change with community health has not been considered a priority topic because community health is a multifaceted societal issue and the primary responsibility for safeguarding and improving it rests with the public sector due to the central role of regulatory authorities and law enforcement.

- **Research and development (R&D):** The impact of climate change on R&D is mostly on disruptions to drug development and difficulty conducting clinical trials. Pharmaceutical stakeholders can leverage findings from earlier parts of this report to inform future research direction, but given that the objective of this report is to provide guidance on cross-sector collaboration, intersections with R&D have not been considered as priority topics.

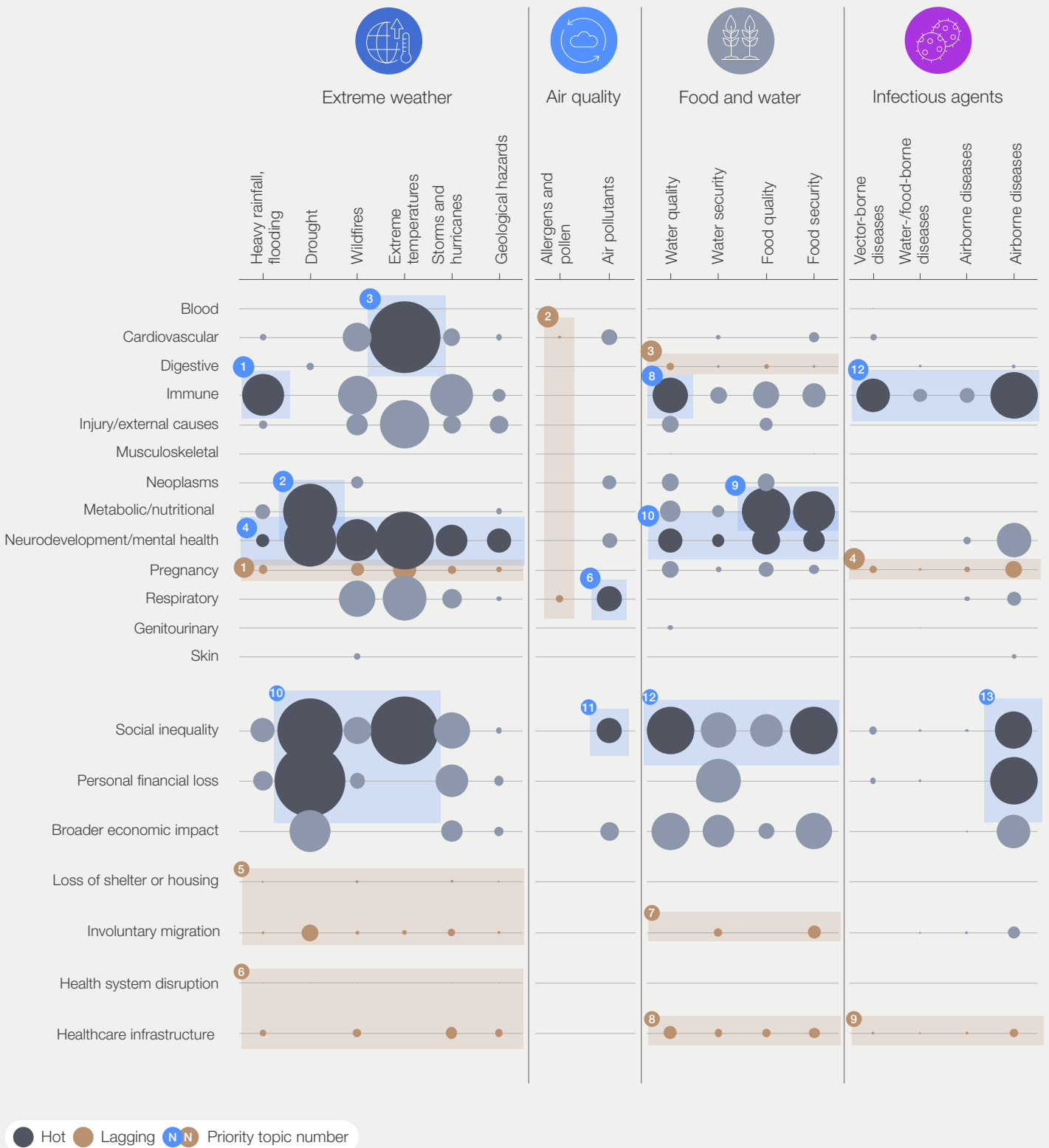
To identify priority topics, each of the four climate change manifestations was evaluated independently to maintain a clear focus on the specific dynamics and challenges of each. Factors taken into consideration include the volume of actionable evidence, the abundance of high-impact intersections for each health impact area (i.e. whether multiple or the majority of intersections between climate change manifestations and a particular health impact areas are classified as high-impact), and the suitability for intervention by the private sector.

Considering all these factors, a total of 22 priority topics for intervention have been identified, the mapping of which is presented in Figure 9 and summarized in Figure 10. Two types of priority topics are identified:

- **Hot topics:** Intersections with higher volume of actionable evidence relative to the other high-impact intersections, representing areas of considerable existing attention, which highlights their critical importance and the need for continued focus and increased private sector intervention to drive further impact.
- **Lagging topics:** Intersections with lower volume of actionable evidence relative to the other high-impact intersections, representing areas of high impact that are currently under-addressed or overlooked, indicating the need for increased attention and resources to mitigate their effects.

FIGURE 9 | Mapping of priority topics for interventions

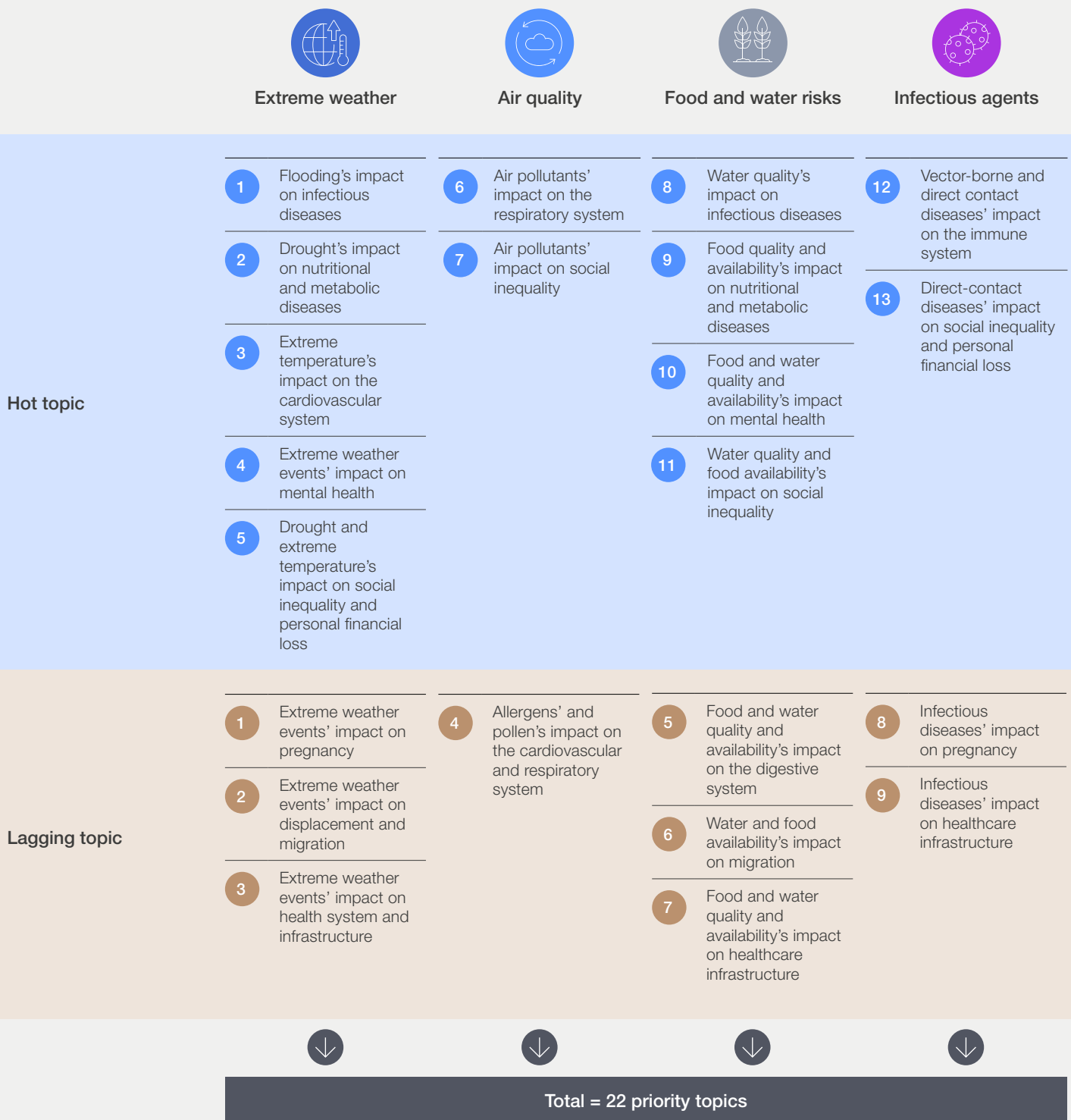
Volume of actionable evidence (represented by bubble size)



**Note:** The sizes of the bubbles are relative only to others within the same climate change manifestation and within each health area type (i.e. the sizes of bubbles cannot be directly compared across multiple climate change manifestations or between direct vs. indirect health areas).

**Source:** L.E.K. Consulting

FIGURE 10 | Priority topics for intervention, by climate change manifestation



Source: L.E.K. Consulting

### Priority health impact areas

The priority topics identified through this mapping exercise lie across a total of 10 health impact areas, seven of which are direct health outcome groups and three are indirect health determinants

(see Figure 11). The following section will discuss findings regarding the priority topics by health impact area.

FIGURE 11 Health impact areas and priority topics identified



Source: L.E.K. Consulting

## Cardiovascular system

The priority topics identified through this mapping exercise lie across a total of 10 health impact areas, seven of which are direct health outcome groups and three are indirect health determinants

(see Figure 11). The following section will discuss findings regarding the priority topics by health impact area.

### Climate change manifestation

### Priority topic



**Extreme weather**

*(Hot topic)*  
Impact of extreme temperature on the cardiovascular system



**Air quality**

*(Lagging topic)*  
Impact of allergens and pollen on the cardiovascular system

As part of the analysis, all intersections between the cardiovascular system and extreme weather, apart from drought, were classified as high-impact (including heavy rainfall and flooding, wildfires, storms and geological hazards). Extreme temperature was prioritized due to the substantial volume of actionable evidence available – nearly three times more than the average for all high-impact intersections between extreme weather and the cardiovascular system. However, actionable evidence still only represents 30% of the total evidence available for extreme temperature’s impact on the cardiovascular system, indicating a gap in research dedicated to providing actionable guidance.

Extreme temperatures – heat or cold – can strain the cardiovascular system from the need to maintain thermoregulation, increasing the risk of heart conditions such as heart attack, arrhythmia and heart failure, which may elevate cardiovascular mortality rates, particularly among the elderly and individuals with pre-existing heart diseases.<sup>56</sup> Early warning systems are vital for reducing

heatwave-related health risks, providing time to health systems and individuals for preparation and action. A pilot project on an early warning system for heatwaves in China, part of a broader initiative funded by the WHO and the United Nations Development Programme (UNDP), emphasized the necessity of multisectoral cooperation in system design and implementation.<sup>57</sup>

The impact of allergens and pollen on the cardiovascular system is a considerably under-researched area, with approximately 80% less actionable evidence available compared to the average for all high-impact intersections between air pollutants and direct health outcome groups. This can be attributed to the limited understanding of how exposure to allergens and pollen links to cardiovascular diseases, with current hypotheses suggesting a potential association with increased levels of proinflammatory cytokines or other inflammatory mediators.<sup>58</sup> Further research into this area can help inform future guidance and potentially help prevent the exacerbation of cardiovascular diseases due to climate change.

## Digestive system

The priority topics identified through this mapping exercise lie across a total of 10 health impact areas, seven of which are direct health outcome groups and three are indirect health determinants

(see Figure 11). The following section will discuss findings regarding the priority topics by health impact area.

### Climate change manifestation

### Priority topic



#### Food and water risks

*(Lagging topic)*  
Impact of food and water quality and security on the digestive system

The intersections between the climate change sub-themes of food and water risks with the digestive system have all been evaluated as high-impact, highlighting the critical vulnerability of the digestive system. However, these intersections are substantially under-researched. The average volume of actionable evidence available for other direct health outcome groups that have high-impact intersections with all food and water risks’ sub-themes (namely immune system/infectious diseases, neurodevelopment and mental health, pregnancy and nutritional and metabolic diseases) exceeds the research available for the digestive system by a factor greater than five.

Consumption of contaminated water is associated with gastrointestinal (GI) illness outbreaks, particularly when sanitation is compromised due to water scarcity.<sup>59</sup> Densely populated, low-

income areas are particularly vulnerable due to inadequate sanitation infrastructure, often with poor sewerage systems and limited access to toilets, leading to increased water contamination risks, especially in low-lying areas vulnerable to stormwater discharge.<sup>60</sup> Contaminated food and food insecurity can lead to food poisoning and infectious GI symptoms such as diarrhoea, vomiting and gastroenteritis. There is also evidence suggesting that alterations to soil composition due to climate change can affect gut microbiota, thereby influencing the incidence of functional GI diseases such as inflammatory bowel disease (IBD) and GI cancers,<sup>61</sup> though additional research is required to inform future treatment needs and a shift in agricultural approaches.

## Immune system and infectious diseases

### Climate change manifestation

### Priority topic



**Extreme weather**

*(Hot topic)*  
Impact of flooding on infectious diseases



**Food and water risks**

*(Hot topic)*  
Impact of water quality on infectious diseases



**Infectious agents**

*(Hot topic)*  
Impact of vector-borne and direct-contact diseases on the immune system

The immune system stands out as a high-impact intersection with nearly all sub-themes within extreme weather, food and water risks, and infectious agents. Specifically, intersections of heavy rainfall, flooding and water quality with vector-borne and direct-contact diseases have been identified as priority areas due to the significant volume of actionable evidence available, ranging from approximately 1.5-3 times higher than other high-impact intersections involving the immune system/infectious diseases.

Notably, within extreme weather, heavy rainfall and flooding was prioritized even though a similarly large volume of actionable evidence was available for wildfires and storms. Heavy rainfall and flooding had the lowest percentage of actionable evidence relative to its total evidence pool, with only 21% of total evidence containing actionable guidance, while actionable evidence represented 40% to 50% of the total evidence available for wildfires and storms.

The intersections of flooding, water quality and vector-borne diseases with the immune system present complex and interconnected challenges that demand immediate attention. Floods and compromised water quality are intrinsically linked, with heavy rainfall and flooding exacerbating water contamination primarily through increased surface run-off and disruptions in sewage and wastewater systems during flooding events, heightening the risk of waterborne diseases.<sup>62</sup> Moreover, stagnant water resulting from heavy rainfall and flooding is fertile breeding ground for disease-carrying vectors such

as mosquitoes, facilitating the spread of vector-borne diseases such as West Nile virus. Low-lying coastal cities susceptible to rising sea levels and flooding are particularly vulnerable to disease outbreaks following natural disasters. Especially in East and Southeast Asia, simultaneous population growth and urban expansion in coastal areas increases the risk of such outbreaks in densely populated areas.<sup>63</sup> These interconnected dynamics highlight the urgent need for measures to enhance water management and sanitation infrastructure. Such actions are critical for safeguarding access to safe drinking water, bolstering resilience against natural disasters to minimize disruptions to water supply and mitigating the proliferation of disease-spreading vectors.

Vector-borne diseases constitute over 17% of all infectious diseases, according to the WHO.<sup>64</sup> Considering how the behaviour and habitat range of disease-carrying vectors are changing with the climate, there is a pressing need for innovative vector-control strategies and a reassessment of geographical demographics to address the shifting distribution of vector populations towards new areas. To address these challenges, the interconnectedness of the health of humans, animals and the environment should be recognized. This integrated approach, bringing together stakeholders across human, animal and environmental health, can lead to more effective control and prevention measures against vector-borne diseases, zoonotic diseases and food safety in the context of climate change.<sup>65</sup>

## Nutritional and metabolic diseases

### Climate change manifestation

### Priority topic



**Extreme weather**

*(Hot topic)*  
Impact of drought on nutritional and metabolic diseases



**Food and water risks**

*(Hot topic)*  
Impact of food and water quality and security on nutritional and metabolic diseases

Nutritional and metabolic diseases are a key health area affected by all four sub-themes of food and water risks, as well as by select extreme weather sub-themes, including heavy rain and flooding, drought and geological hazards. Specifically, the intersections with drought, food quality and food availability emerged as priority hot topics due to the two to four times higher volume of actionable evidence available compared to the other high-impact intersections involving nutritional and metabolic diseases, indicating their critical importance and the ongoing need for focused action.

The increasing frequency and severity of droughts pose a growing risk of malnutrition for millions worldwide. The Horn of Africa, for example, experienced its worst drought in 40 years in 2022, leaving over 1.7 million children across Ethiopia, Kenya and Somalia in urgent need of treatment for severe acute malnutrition.<sup>66</sup> Apart from reducing crop yield, droughts also deplete soil nutrients, exacerbating global micronutrient deficiencies estimated to affect more than 2 billion people.<sup>67</sup> Beyond malnutrition, limited food variety and reduced intake can also increase the risk of metabolic conditions. For instance, chronic food insecurity has been linked to the development of diseases such as type-2 diabetes.<sup>68</sup>

Initiatives to fortify food, particularly through private sector partnerships, have shown promise in addressing nutritional deficiencies.<sup>69</sup> However, agricultural interventions focusing on sustainable and resilient agricultural practices, such as multi-cropping and cover cropping, and increasing the use of agricultural technologies such as satellite imagery and crop and soil simulators, are essential for preventing nutritional and metabolic diseases caused by climate change. This is especially true given that agriculture is the primary source of livelihood for 86% of rural populations globally, who are also the most vulnerable to hunger and malnutrition.<sup>70</sup>

Moreover, the contamination of food with pesticides poses the significant health risk of disruption to hormonal function.<sup>71</sup> Considering heightened pesticide contamination risks due to surface run-offs from heavy rainfall and increased volatilization from increased temperatures,<sup>72</sup> there is a pressing need for further research to understand the precise mechanisms through which pesticides affect the hormonal system.

## Neurodevelopment and mental health

### Climate change manifestation

### Priority topic



**Extreme weather**

*(Hot topic)*  
Impact of extreme weather on mental health



**Food and water risks**

*(Hot topic)*  
Impact of food and water quality and availability on neurodevelopment and mental health

All intersections of extreme weather and food and water risks with neurodevelopmental and mental health were evaluated as high-impact intersections. These were selected as priority hot topics given the consistent and significant impact by both climate change manifestations. Research indicates extreme

weather events are strongly correlated with an increase in the occurrence and severity of mental health and neurological disorders. This includes a range of conditions such as depression, anxiety, memory impairment, sleep disturbances and isolation, as well as risk of self-harm and suicide.<sup>73</sup>

Livelihood disruptions and displacement, triggered by extreme weather events, can have profound effects on individual, family and community support mechanisms. These disruptions may include loss of employment, damage to property and the depletion of financial resources, which can destabilize the foundational support systems that individuals rely on for day-to-day functioning. Additionally, the strain on community resources, such as healthcare, education and local governance, can further erode the resilience of communities.

Collectively, these factors contribute to a pervasive sense of insecurity and significantly elevate the risk of psychological distress among those affected. During a crisis, emotional distress is a common and expected reaction and most individuals tend to improve when appropriate supports are provided. These supports, which aim to strengthen individual, familial and community systems, play a crucial role in fostering resilience and facilitating recovery.



However, some individuals may experience more severe distress that impairs their daily functioning and requires targeted psychological interventions. A small percentage of these cases may necessitate specialized clinical care to address more complex mental health needs. According to the IASC MHPSS Guidelines (2007), recognizing the varied levels of support needed is essential in tailoring interventions that effectively address the continuum of mental health challenges following a crisis. Particularly vulnerable are children and individuals with pre-existing mental health conditions or physical disabilities, who may experience prolonged psychological distress following natural disasters.<sup>75</sup>

Similarly, water and food insecurity compounds stress and social isolation, increasing the risk of depression, anxiety and suicide.<sup>76</sup>

Beyond these mental health concerns, the increasing threat to water and food quality and security also has implications for neurocognitive conditions. For instance, childhood exposure to substances like mercury, arsenic and prions has been shown to have long-term neurotoxic effects.<sup>77</sup> This risk is heightened by the changing soil and water chemistry resulting from climate change, which is increasing the bioavailability of such neurotoxic substances.<sup>78</sup> Additionally, childhood malnutrition is associated with impaired cognitive development.<sup>79</sup>

In response to these challenges, it is vital to promote and protect the mental health and psychosocial well-being of all communities, including the most vulnerable, at all levels of climate action policies and plans – from preparedness and prevention to response and recovery. This includes strengthening promotive and preventative mental health and psychosocial services in the community; developing or improving mental health service delivery systems, and ensuring equitable access to care, training and support for first responders across sectors to recognize and address mental health needs; reducing the risk of food and water contamination; preserving livelihoods dependent on food and water availability; and minimizing social and economic disruption following natural disasters.

## Pregnancy and the perinatal period

Climate change manifestation	Priority topic
 <b>Extreme weather</b>	<i>(Lagging topic)</i> Impact of extreme weather on pregnancy
 <b>Infectious agents</b>	<i>(Lagging topic)</i> Impact of infectious diseases on pregnancy

The impact of climate change on pregnancy represents a key under-researched climate-health intersection. Almost all intersections of extreme weather, food and water risks, and infectious agents with pregnancy were assessed as high impact, but the volume of actionable evidence available was two to three times less than that available for other health areas that are also consistently affected. Furthermore, only 30% of all evidence that identified the impact of extreme temperature and geological hazards on pregnancy contained actionable guidance.

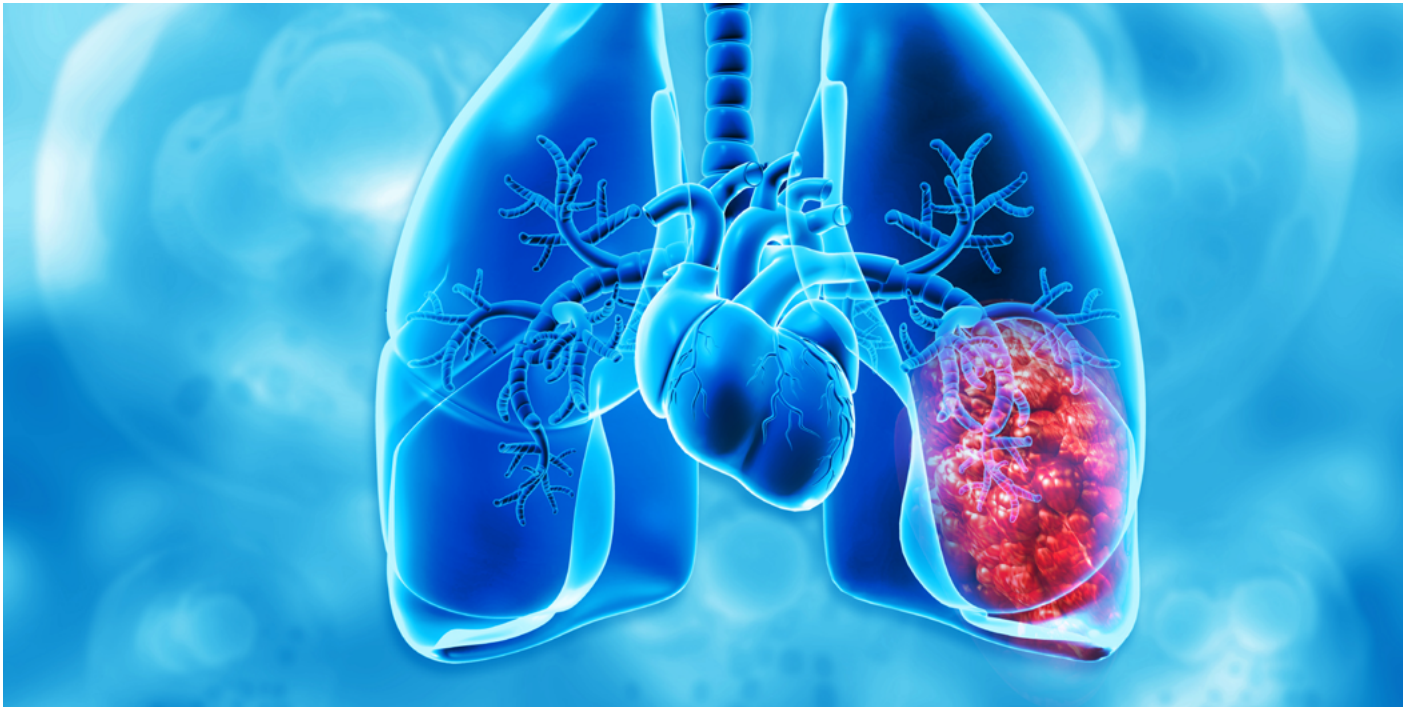
Exposure to extreme weather events and its secondary effects, such as poor air quality resulting from wildfires, psychological distress from physical damage or livelihood disruption, and nutritional deficiency from food supply disruption, have been linked to a range of adverse pregnancy outcomes. These include preterm birth, labour complications, miscarriage, impaired foetal growth and birth defects.<sup>80</sup> Additionally, temporary immunosuppression due to viral infection, heightened dehydration and reduced oxygen



availability in maternal blood due to infectious diseases can increase the risk of maternal anaemia, miscarriage, premature delivery and low birth-weight.<sup>81</sup>

As a “lagging” topic with limited actionable evidence, there is a pressing need for further research to understand how extreme weather events and infectious diseases impact maternal and neonatal health. This research can provide valuable insights into treatment needs and interventions to improve pregnancy outcomes.

Additionally, enhancing access to medical care and health monitoring solutions is essential for mitigating the health impacts of climate change on pregnant women. This is especially crucial in LMICs, such as those in sub-Saharan Africa and South Asia, where the level of antenatal care is already low and where populations are at a higher risk of natural disasters and face a higher disease burden.<sup>82</sup> Closing the healthcare access gap in these regions is vital for safeguarding the health and well-being of pregnant women and their infants in the face of climate-related challenges.



## Respiratory system

### Climate change manifestation

### Priority topic



**Air quality**

*(Hot topic)*  
Impact of air pollutants on the respiratory system







**Air quality**

*(Lagging topic)*  
Impact of allergens and pollen on the respiratory system

The impact of air quality on the respiratory system is a subject of heightened interest but has received varying degrees of research. While the effects of air pollutants are widely recognized, awareness regarding allergens and pollen remains comparatively low. This discrepancy is highlighted by the substantial disparity in the volume of actionable evidence available, with research on the respiratory impact of air pollutants outweighing that of allergens and pollen by a factor of 3.5.

Moreover, the elderly are particularly vulnerable to the detrimental health impacts of poor air quality because they often have pre-existing chronic lung and cardiovascular conditions coupled with diminished immunity associated with aging.<sup>83</sup> Given this disparity, additional research into understanding the respiratory effects of allergens and pollen is critically important. Moreover, the development of improved monitoring solutions, such as pollen count forecasting and reporting, can enhance community preparedness and reduce overall exposure to respiratory hazards.<sup>84</sup>

## Social inequality and personal financial loss

Climate change manifestation	Priority topic
 <b>Extreme weather</b>	<i>(Hot topic)</i> Impact of drought and extreme temperature on social inequality and personal financial loss
 <b>Air quality</b>	<i>(Hot topic)</i> Impact of air pollutants on social inequality
 <b>Food and water risks</b>	<i>(Hot topic)</i> Impact of water quality and food security on social inequality
 <b>Infectious agents</b>	<i>(Hot topic)</i> Impact of direct contact diseases on social inequality and personal financial loss

Social inequality has high-impact intersections with all climate change sub-themes apart from allergens and pollen, highlighting it as a key area of vulnerability to climate change. Specifically, the intersections with drought, extreme temperatures, air pollutants, water quality, food security and direct contact diseases emerged as priority hot topics due to the substantial volume of actionable evidence available for these intersections – up to three times higher than the average volume of evidence available for other high-impact intersections involving social inequality.



For personal financial loss, drought and direct-contact diseases were prioritized given that the volume of actionable evidence available was up to six times higher than for other high-impact intersections involving personal financial loss. This highlights the critical importance of addressing the financial impact of drought and direct-contact diseases and the ongoing need for focused action.

Personal financial loss is closely connected with social inequality, as marginalized communities often lack access to insurance and loans and rely

heavily on climate-dependent livelihoods such as agriculture. Consequently, financial loss is one way in which climate change amplifies social inequality. Wealth disparities intensify the vulnerability of marginalized populations to the adverse impacts of climate change, thereby perpetuating a vicious cycle of inequality and poor health outcomes. For instance, droughts disproportionately affect women in developing countries, as women constitute over 50% of the global agricultural workforce but possess significantly fewer land rights and decision-making power.<sup>85</sup> Air pollution has a greater impact on lower-income groups, as they tend to live in more polluted industrial areas with limited green spaces.<sup>86</sup> Importantly, vulnerable populations often have restricted access to healthcare services due to financial constraints or because they reside in rural areas lacking medical facilities.<sup>87</sup>

To effectively address the impact of climate change on social inequality, it is crucial to rectify these pre-existing inequities, ensuring that the most vulnerable communities receive adequate support and empowerment to withstand the challenges posed by a changing climate.

## Displacement and migration

Climate change manifestation	Priority topic
 <b>Extreme weather</b>	<i>(Lagging topic)</i> Impact of extreme weather events on displacement and migration
 <b>Food and water risks</b>	<i>(Lagging topic)</i> Impact of water and food availability on involuntary migration




Displacement and migration emerged as a priority topic given that they are significantly affected by all extreme weather sub-themes (heavy rainfall and flooding, droughts, extreme temperatures, etc.) and due to the consistent lack of actionable evidence compared to other indirect health impact areas. All extreme weather sub-themes are likely to cause involuntary migration due to safety risks or livelihood disruptions. Additionally, with the exception of droughts and extreme temperatures, they can also lead to displacement due to housing or shelter damage.<sup>88</sup>

The Internal Displacement Monitoring Centre attributed an average of 22.5 million internal displacements to weather-related disasters from 2008 to 2022,<sup>89</sup> and 75% of global displacements in 2020 to natural disasters.<sup>90</sup> Likewise, scarcity of or compromised access to food and water can prompt both internal and international migration.

According to the UN, water deficits alone are linked to approximately 10% of the surge in global migration between 1970 and 2000.<sup>91</sup>

To address displacement and migration, it is essential to build community resilience against natural disasters and food and water insecurity, with a particular emphasis on developing countries that are disproportionately affected by these challenges. For instance, in 2022, Afghanistan, Bangladesh, the Philippines, Haiti and Senegal emerged as the five countries most affected by climate displacement.<sup>92</sup> Yet, this critical topic is currently under-researched and lacks actionable guidance, highlighting the urgent need for awareness creation and action. This demands collaborative efforts between the private and public sectors to secure funding, improve infrastructure, enact policy changes and engage communities in adopting resilient approaches.

## Health systems and infrastructure disruption

Climate change manifestation	Priority topic
 <b>Extreme weather</b>	<i>(Lagging topic)</i> Impact of extreme weather on healthcare system and infrastructure disruption
 <b>Food and water risks</b>	<i>(Lagging topic)</i> Impact of food and water quality and security on healthcare system and infrastructure disruption
 <b>Infectious agents</b>	<i>(Lagging topic)</i> Impact of infectious diseases on healthcare system and infrastructure disruption

Healthcare systems and infrastructure were identified as priority "lagging" topics across extreme weather, food and water risks, and infectious agents, due to their susceptibility to climate change impact across these three climate change manifestations and the consistently lower volume of actionable evidence available compared to other high-impact intersections.

Food and water security, extreme weather events and infectious disease outbreaks present distinct challenges to healthcare systems and infrastructure but also have similar disruptive impacts: they disrupt supply chains, leading to shortages of critical medical supplies;<sup>93</sup> they cause sudden increase in patient admissions due to mass casualties; and contaminated food and water sources and infectious agents can trigger large-scale disease outbreaks.<sup>94</sup>

Routine healthcare services can also be disrupted as resources are redirected, particularly during disease outbreaks, towards outbreak control

and containment measures.<sup>95</sup> Additionally, water insecurity compromises sanitation standards in healthcare facilities, while extreme weather events such as hurricanes and earthquakes pose a unique threat of direct physical damage to healthcare facilities, potentially rendering them temporarily or permanently inoperable.<sup>96</sup>

Addressing these challenges requires improved resilience measures and response capacities. This highlights the critical role of the private sector in enhancing infrastructure and supply chain resilience, expanding access to healthcare services and advancing disaster prediction and preparedness through innovative technologies. All this requires cross-sector collaboration, including engagement with the health workforce to enhance response preparedness and policy changes enacted by the public sector to drive healthcare access expansion.

2

# Engaging the private sector in climate-health interventions

Translating insights into impact requires collaborative action in the fight against climate change.

## Involvement of the private sector is not only beneficial but necessary

The climate-health nexus analysis detailed in this report provides a foundation for future action by pinpointing priority climate-health intersections that are most in need of targeted interventions.

While the public sector shoulders significant responsibility in responding to climate change emergencies, private sector involvement is vital for accelerating and augmenting these efforts. The 2022 Global Landscape of Climate Finance showed that private climate finance has been increasing at half the rate of public finance.<sup>97</sup> Private organizations possess specialized knowledge and expertise across various industries, which can be leveraged to augment the public sector's response capabilities. By tapping into industry-specific insights and resources, collaborative efforts can adopt a more comprehensive and coordinated approach:

- **Innovation and technology:** Private sector innovation drives the development of cutting-edge technologies and solutions to address climate and health challenges, leading to improved resilience and health outcomes.
- **Expertise and specialization:** Private organizations bring expertise and experience as well as specialized skills across diverse industries to climate and health interventions, which can provide valuable insights and tailored approaches for climate interventions.

- **Financial resources:** Private sector partnerships can mobilize significant financial resources for research, development and implementation of interventions, unlocking new funding sources and investment opportunities.
- **Efficiency and scale:** As businesses often have more agile and adaptable operational capabilities, private sector involvement can enhance efficiency, cost-effectiveness, and scalability of interventions, optimizing processes and maximizing resources for widespread impact.
- **Accountability and credibility:** With appropriate accountability mechanisms, greater involvement of the private sector can ensure adherence to rigorous standards, regulations and best practices, ensuring the integrity and effectiveness of interventions.

Furthermore, as the manifestations of climate change become more frequent and severe, businesses face escalating risks, such as interruptions, physical damage and adverse effects on staff health and productivity. Recognizing these risks, private sector involvement becomes not only beneficial but necessary to safeguard business interests and strengthen community resilience.

## Sectors and industries need to act together

To achieve a comprehensive and sustained response to climate-induced health challenges, collaborative efforts between the private sector and other stakeholders, such as public institutions, non-governmental organizations and communities, are essential. While the pharmaceutical and healthcare sectors hold pivotal positions, other

sectors such as energy and utilities, transportation and agriculture, wield considerable influence on mitigating the impact of climate change on health. By embracing partnerships and sharing expertise, they can develop holistic solutions that address the multifaceted impacts of climate change on public health.

## Particular populations are disproportionately vulnerable to the health consequences across all priority topics identified

Across the priority topics identified, infants and children, women (pregnant and non-pregnant), the elderly, and lower-income individuals and countries consistently emerge as highly vulnerable. This is driven by a mix of physiological, geographical and social factors, often overlapping between populations.

Infants, children, the elderly and pregnant women are particularly susceptible across priority health areas due to weakened physiological functions stemming from immaturity, frailty and pregnancy-related alterations, making them less adaptable to environmental shifts, such as increasing temperatures, and less effective in combating infections.<sup>98</sup> Pregnant women face additional risks to both maternal and foetal health, including complications such as anaemia, low birth weight and miscarriage.<sup>99</sup> Notably, air pollution is implicated in approximately 20% of newborn deaths.<sup>100</sup> Women, in general, face heightened vulnerability due to gender inequality, with their livelihoods more reliant on natural resources and limited capacity to withstand and recover from natural disasters.<sup>101</sup>

Geographical vulnerability and social vulnerability are deeply intertwined in climate change's health impacts. While countries such as the United States (US) and Australia are also prone to environmental

hazards like heat waves and wildfires, they are generally more able to implement effective measures as they have the requisite financial resources.<sup>102</sup> In contrast, lower-income countries, including many in Africa and among the Small Island Developing States in the Caribbean and Pacific regions, lack adequate resources to cope with hazards like rising sea levels, extreme heat, vector-borne diseases and food insecurity.<sup>103</sup>

Nevertheless, vulnerability extends beyond national borders, encompassing socially disadvantaged populations within and outside these countries. These marginalized groups, including lower-income individuals and racial minorities, confront interconnected challenges, including higher rates of pre-existing medical conditions, substandard living conditions and limited access to healthcare services.<sup>104</sup> Their vulnerability is compounded by restricted digital connectivity and technological resources, limiting their ability to access critical information and support.

In developed countries too, rural populations face vulnerabilities due to limited digital access and healthcare services.<sup>105</sup> This intricate web of geographical and social vulnerabilities underscores the urgent need for comprehensive, equity-focused approaches to climate resilience and adaptation.

## A comprehensive approach to mitigating the health impacts of climate change is required

To address the priority topics identified in a sustainable and effective manner, it is critical to understand their underlying drivers.

To ensure a comprehensive response that encompasses both prevention and reaction, interventions should aim to achieve three main objectives:

- **Resilience:** Interventions should focus on enhancing the ability and capacity to foresee and better manage the adverse effects of climate change and recover quickly from its impacts.
- **Response:** Interventions should be conducted during or immediately after climate events/circumstances, focusing on saving lives and protecting community assets.

- **Recovery:** Interventions should be sustained over a longer time horizon, spanning months to years after climate events/circumstances, aimed at supporting affected communities by restoring physical infrastructure as well as social, economic, emotional and physical well-being.

Currently, while funding for renewable energy has seen the most substantial increase within climate finance, there is a notable shortfall in adaptation and resilience finance, especially in crucial sectors including agriculture, forestry, land use, industry and water management.<sup>106</sup>

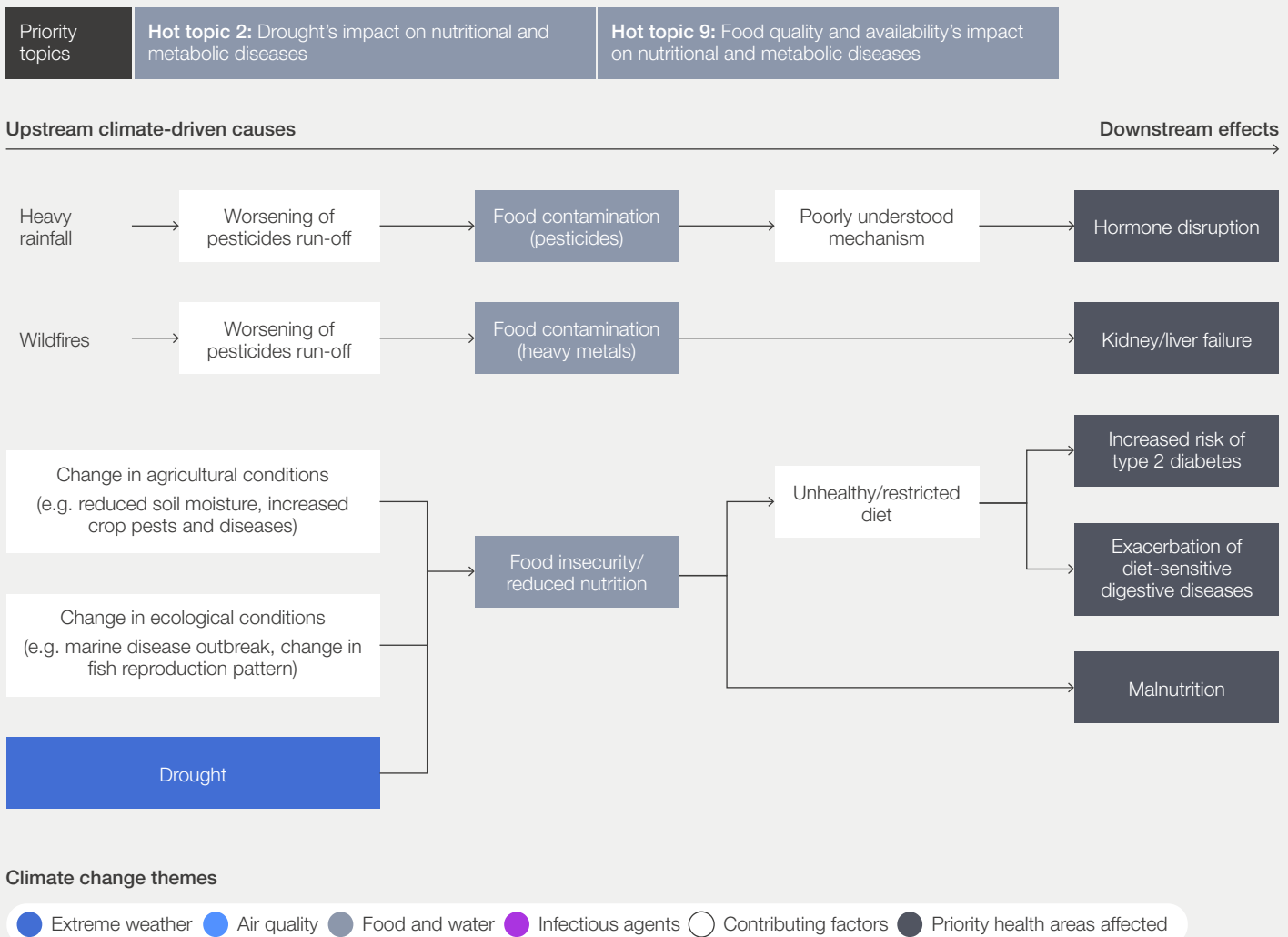
## 2.1 Identification of key underlying factors

For the 22 priority topics, a detailed analysis helped identify the key underlying, contributing factors that add to the direct effects of climate change on people's health (see Figure 12 as an example; the causal chain analysis for other priority topics can be found under section A4 in the appendix).

This analysis aimed to identify the necessary interventions, specifically focusing on opportunities for private sector involvement. (The analysis focused on the most important drivers linking climate change to its health impacts, and may not be exhaustive of all potential contributing drivers.)

FIGURE 12 Health impact areas and priority topics identified

### Nutritional and metabolic diseases



**Note:** The analysis focused on the contributing factors with the most severe downstream effects and most closely linking climate change to its health impact, and may not be exhaustive of all potential contributing factors.

**Source:** L.E.K. Consulting

Consolidating all contributing factors identified from this analysis, 12 systemic drivers emerged across the priority topics, as summarized in Figure 13. These drivers can be grouped into four categories based on their role in the causal chain, with some drivers fitting into multiple categories:

- **Primary contributor:** The initial and most immediate effects of climate change, serving as the starting point of the causal chain.
- **Secondary contributor:** While not directly caused by climate change, these drivers arise due to primary contributors and add to downstream health consequences.

- **Amplifiers:** Pre-existing factors that exacerbate the severity of primary and secondary drivers, as well as the health impact of climate change.
- **Health impact:** The resulting consequence on health due to upstream drivers, which are often the end of the casual chain, though in some cases may also act as a contributing factor that perpetuates further health impact.



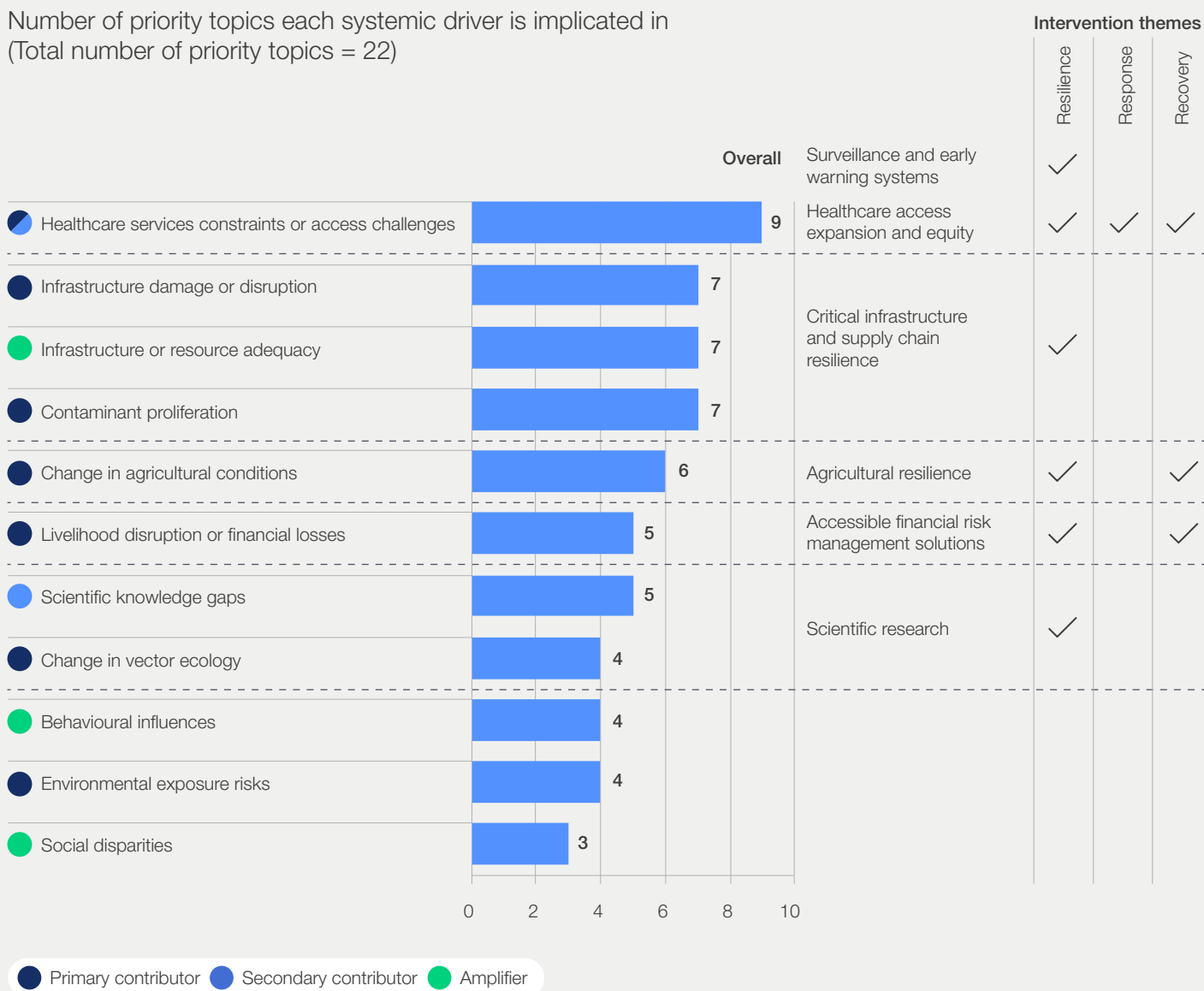
## 2.2 Identification of interventions

The causal chain analysis shows that many systemic drivers initiate the causal chain. This reinforces the fundamental interconnectedness of the health impacts of climate change, with many health challenges sharing common root causes. Figure 13 ranks the systemic drivers by the number of priority topics they are associated with. By prioritizing the top nine driver types, six key thematic areas for intervention were identified as crucial for mitigating the broad spectrum of the health consequences of climate change. Focusing on these intervention themes would enable the development of resilience-building strategies, equipping communities and healthcare systems with the adaptive capacity to withstand and effectively respond to environmental challenges.

While the remaining three driver types should not be disregarded, “behavioural influences” and “social disparities” are more pertinent for NGO and public sector involvement, respectively. The former primarily requires community engagement and education initiatives, while the latter represents deeper-rooted, systemic issues that require policy reforms. “Environmental exposure risks”, such as heightened vulnerability to air pollutants and extreme temperatures, call for community education on individual protection strategies, which align less well with initiatives requiring private sector engagement.

FIGURE 13 Systemic drivers and thematic areas for intervention

Number of priority topics each systemic driver is implicated in (Total number of priority topics = 22)



### Surveillance and early warning systems

	Resilience	Response	Recovery		Target systemic driver	Primary	Secondary	Amplifier
<b>Intervention type</b>	✓	✓	○		Overall (majority of drivers)	✓	✓	✓

Surveillance and early warning systems (EWS) provide a critical head-start for enacting emergency plans and taking precautionary measures for individuals, communities, governments and businesses. This helps reduce damage and loss, making surveillance and EWS indispensable in safeguarding against disease outbreaks and atypical weather events. According to the “Atlas of Mortality and Economic Losses from Weather,

Climate and Water-related Hazards” report, improved EWS and disaster management have reduced the number of disaster-related deaths by almost three-fold between 1970 and 2019.<sup>107</sup>

It is vital to recognize that successful implementation of a comprehensive surveillance and EWS hinges on three key pillars: timely and accurate forecasting and monitoring, effective



risk communication and implementation of preparedness activities.<sup>108</sup> The private sector has a significant role to play in bolstering all three pillars, with particular emphasis on the first two.

According to the United Nations Office for Disaster Risk Reduction (UNDRR), the number of countries with early warning systems has doubled since 2015, thanks to technological advancement.<sup>109</sup> The private sector plays a vital role in advancing these efforts, leveraging technological innovations such as artificial intelligence (AI) and digital platforms to enhance the accuracy and timeliness of data collection, risk assessment and hazard forecasting. The Early Warnings for All initiative led by the World Meteorological Organization (WMO) and UNDRR is a global public-private initiative that aims to ensure universal protection from hazardous weather and climate events by the end of 2027. Since its launch in late 2022, several leading technology companies have joined the initiative.

In the context of infectious diseases, the 2022 “Access to Medicine Index” flagged the very limited R&D and pipeline activity dedicated to emerging infectious diseases (EIDs), with only five of the 20 leading pharmaceutical companies reviewed being active in this area. However, the research efforts of these five companies still only cover a minority of EIDs that are likely to trigger future pandemics or epidemics.<sup>110</sup> Sharing of disease surveillance data remains a key barrier in the speed of R&D into EIDs. However, COVID-19 provided a great example of how unprecedented data-sharing enabled rapid development of medical knowledge and effective vaccines to protect public health.<sup>111</sup>

To better prepare against future outbreaks, pharmaceutical companies and academia have significant collaboration opportunity to accelerate R&D activity in EIDs. Their collaboration with the public sector could help develop infrastructure and an appropriate regulatory environment to incentivize data-sharing.

Risk communication is the second key pillar for successful implementation of EWS by ensuring that valuable insights derived from monitoring and forecasting tools are communicated effectively to the public. Private sector stakeholders in the media and telecommunications sectors can play a role in facilitating timely and accurate information dissemination. For example, during the COVID-19 pandemic in Iran, a digital application for providing data on incidence and mortality rates, risk maps and other information was developed in partnership with the private sector.<sup>112</sup>

However, affordability remains a key barrier in the deployment and implementation of EWS, especially in low-income countries. As of 2023, just over half of all countries globally were covered by multi-hazard early warning systems (MHEWS), with particularly low coverage in the Americas, the Caribbean and Africa. The UNDRR highlighted the benefit of strengthening and expanding mobile networks and internet connectivity, particularly for short-notice hazards like tsunamis. Private sector investments and public-private collaboration offer significant potential in scaling up and driving technology innovation for more inclusive and accessible multi-hazard EWS.



**In a world defined by escalating climate injustices, early warning systems are the most basic tool for saving lives and securing livelihoods. Countries that are vulnerable to extreme weather, especially Small Island Developing States and Least Developed Countries and the entire African continent, should have the highest rates of protection but they are well below the global average.**

António Guterres, Secretary-General, United Nations



## Healthcare access expansion and equality

	Resilience	Response	Recovery	Target systemic driver	Primary	Secondary	Amplifier
<b>Intervention type</b>				Healthcare services constraint/access challenges			
<p>It is evident that climate change increases the demand for health services, particularly within priority topics identified such as pregnancy care, with heightened risks arising from extreme temperatures and infectious disease outbreaks. Accessibility of healthcare services plays a complex role in the causal chain between climate change and its health impacts, acting as a primary and secondary driver as well as an amplifier. For example, health services are susceptible to direct disruptions due to extreme weather events or large-scale water contamination that compromise healthcare facilities and can also act as a secondary driver if a surge in patient numbers overwhelms the healthcare system and hinders its ability to provide emergency and routine services.</p> <p>Importantly, existing disparities in access to healthcare further amplify the adverse health effects of climate change. According to a 2023 report by the World Bank and the WHO, more than half of the global population lacks access to essential health services and approximately 1.3 billion people are pushed (further) into poverty due to out-of-pocket healthcare expenses.<sup>113</sup> As such, expanding healthcare access is a critical component of an effective climate adaptation strategy.</p> <p>Access to mental health services also remains a significant area of unmet need, particularly in the context of natural disasters. The long-term mental health impacts of these events highlight a severe inadequacy in disaster-focused mental health services, spanning promotion, prevention and care. This gap is further exacerbated by chronic underfunding in the mental health sector. Highlighting this, reports by the WHO<sup>114</sup> and UNICEF<sup>115</sup> have called for immediate action to address these deficiencies and ensure that vulnerable populations receive the necessary support during critical times.</p> <p>To comprehensively address healthcare access needs and promote resilience as well as enhance response and recovery efforts against the health impacts of climate change, two primary factors must be considered: the provision of care and the accessibility of care.</p> <p>To ensure adequate care provision, it is crucial to bolster the disaster preparedness of frontline health workers and healthcare facilities, particularly in LMICs already grappling with resource and capacity constraints for routine demands. Training healthcare staff in emergency response protocols, including triage, patient management and</p>	<p>psychological first aid, help equip frontline workers with the essential knowledge and skills needed to provide effective medical care during crises.<sup>116</sup> This imperative presents manifold opportunities for various stakeholders to contribute to provision of training. For instance, the approach of the United Kingdom (UK) during the pandemic, which involved leveraging independent providers for enhanced training access, serves as a model for collaboration between public and private health providers.<sup>117</sup></p> <p>Furthermore, there is potential for public-private-philanthropic partnerships to support localized training of healthcare workers in addressing specific diseases exacerbated by climate change. For example, focusing on cardiovascular and maternal health risks in the context of extreme heat can be a targeted area for skill development and capacity building among healthcare professionals. In many LMICs where private healthcare plays a significant role, engaging the private sector is particularly promising. For instance, in Pakistan, contracting with private providers has successfully expanded access to services in remote areas and improved the functioning of public sector facilities.<sup>118</sup></p> <p>Drawing from lessons learned during the COVID-19 pandemic, private sector resources and expertise have been instrumental in bolstering the delivery of health goods and services, including the provision of healthcare equipment, facilities and personnel to treat both COVID-19 and non-COVID patients. However, while leveraging private providers offers the potential to rapidly expand access to health services, public intervention to ensure meticulous governance is essential to ensure optimal capacity utilization and the sustainability of such initiatives.</p> <p>When considering the accessibility of care, achieving universal healthcare remains a complex endeavour, requiring effective leadership from the public sector to address challenges related to governance, regulations and financing. Nonetheless, healthcare innovators can accelerate the digital transformation by developing technologies and collaborating with local healthcare systems and non-profit organizations to expand access. Digital health solutions, in particular, offer novel avenues for delivering critical care closer to patients, especially in remote or underserved areas. While digital health companies have begun expanding care in rural regions globally, significant gaps persist – for example, a survey conducted by a Mumbai-based company showed that only 25% of the semi-rural and rural population had health facilities within reach.<sup>119</sup> Collaboration with</p>						

telecommunication providers should also be explored to expand access to network infrastructure and digital devices. The private sector can also actively participate in capacity-building initiatives and collaborate with public entities to ensure the long-term sustainability of healthcare delivery.

The need to build resilient and sustainable health systems has never been more pressing, given the diverse array of escalating health risks. However, achieving this mission necessitates a collaborative effort across the public, non-profit and

private sectors. It is essential for these sectors to engage in meaningful dialogue and forge stronger partnerships. An example is the Partnership for Health System Sustainability and Resilience, in which the Forum participates actively alongside partners such as the WHO Foundation, the London School of Economics, AstraZeneca and other industry players. By harnessing innovation and fostering closer collaboration with the public sector, the private sector can assume a pivotal role in advancing universal healthcare and mitigating the health impacts of climate change.

## Critical infrastructure and supply chain resilience

Intervention type	Resilience	Response	Recovery
	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Target systemic driver</b>	Primary	Secondary	Amplifier
Infrastructure damage/disruption	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Infrastructure/resource inadequacy	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Contaminant proliferation	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

Critical infrastructure – spanning the water, energy, transportation, communications and health sectors – is susceptible to direct damage or disruption from destructive extreme weather events. Its functioning can also be compromised by large-scale water contamination. The failure or inadequacy of critical infrastructure exacerbates the detrimental impact of climate change on health, such as disruptions in sewage and wastewater disposal, which can be key drivers of the impact of flooding on infectious diseases,<sup>120</sup> while housing destruction caused by extreme weather events leads to displacement.

Supply chain disruptions further compound these challenges. Notably, in many LMICs, the availability of essential medicines in healthcare facilities remains severely inadequate, primarily due to inefficient supply chains, even outside of the context of climate threats.<sup>121</sup> Monetary losses from destruction of critical infrastructure and the resulting operational disruptions can also incur monetary costs detrimental to individuals and society, particularly for low-income populations. In certain Caribbean nations, the economic losses incurred from hurricanes in recent years have surpassed their GDP.<sup>122</sup>

Furthermore, with increasing risk of food and water contamination, primarily from chemical and microbial sources, the existing inadequacy of sanitation and processing infrastructure is becoming increasingly concerning. Investing in climate-resilient infrastructure is key to reducing the monetary and physical loss and damages incurred that can perpetuate downstream direct and indirect health effects.

Companies in the energy, construction and transportation industries play a pivotal role in addressing these issues by enhancing the durability and reliability of critical infrastructure. This may entail deploying innovative technologies to monitor infrastructure integrity, retrofitting existing systems to withstand severe weather conditions and diversifying supply chains to mitigate disruption risks.<sup>123</sup> Particularly in less developed nations, interventions may revolve around installing essential infrastructure for basic services that are currently lacking.

The private sector often engages in this area by forming partnerships with global international organizations and/or local non-profit organizations familiar with community needs. In addition, maintaining and expanding the hardware required for connectivity, such as masts, satellite dishes, reliable electricity and mobile devices, is crucial for effective disaster response and communication and to enable innovative approaches such as digital health solutions. The private sector can also contribute personnel, expertise, physical resources and financial funds to support various initiatives.

These initiatives can include providing critical infrastructure security to accelerate the development of climate resilience projects.<sup>124</sup> For instance, learning from the damages caused by some of the most destructive hurricanes, the federal government and some states in the US have started partnering with businesses in the architecture, engineering and construction industries for climate-resilient public infrastructure projects.<sup>125</sup>

## Agricultural resilience

Resilience Response Recovery

Intervention type



Target

systemic driver

Primary

Secondary

Amplifier

Change in agricultural conditions



Agriculture is one of the sectors most directly and profoundly impacted by climate change and is in urgent need of interventions due to its critical relevance to priority topics involving food and water, as well as flooding and drought. The challenges faced by agriculture are diverse and complex, ranging from shifts in natural agricultural conditions such as water availability and soil nutrition to the physical risks posed by extreme weather events. Emerging risks, including increased pest infestation and crop diseases, further compound these challenges, leading to adverse effects on crop yield and quality and exacerbating food insecurity.

Agriculture serves as a cornerstone of food security and the prevention of downstream health effects, including nutrition, mental health, social inequality and financial loss. Its significance is particularly notable in developing countries, where agriculture accounts for 59% of jobs.<sup>126</sup> Enhancing agricultural resilience not only promotes resilience in the face of changing agricultural conditions, but also ensures faster recuperation and recovery from climatic events, such as facilitating better pasture recovery following droughts. Particularly vulnerable are smallholder farmers, who are responsible for a third of the global food supply but are increasingly facing challenges exacerbated by climate change.<sup>127</sup>

These farmers often lack resources and educational opportunities to adapt to shifting climatic patterns and diminishing yields. Hence, any meaningful intervention aimed at bolstering agricultural resilience must consider the plight of these smallholder farmers and recognize their central role in global food security and poverty reduction.

Innovative agricultural technology (agritech) companies have been leading the way in developing new tools and approaches to tackle the various problems farmers face due to climate change, such as farm management software and precision

farming methods. Moreover, stakeholders such as multinational corporations and agribusinesses wield considerable influence in shaping the resilience narrative. By forging direct partnerships with their suppliers and farmers, these entities can spearhead transformative initiatives aimed at promoting sustainable and resilient agricultural practices.

In addition to providing financial and physical resources to support adoption of innovative agricultural models - such as indoor vertical farming facilities and scientific research in genetic modification or resilient crop varieties - imparting education and support to help farmers adapt to evolving climatic conditions is also crucial.

Cross-sector collaboration is vital for driving adoption of resilient agricultural practices. Engaging farmers in this process can be facilitated independently or through partnerships with local agencies or NGOs, leveraging their knowledge of local ecosystems, agricultural practices and food systems. Furthermore, involvement of the public sector is indispensable in creating conducive regulatory frameworks, allocating funding and safeguarding societal interests in the pursuit of agricultural resilience.<sup>128</sup>

In the broader context of food security, the private sector's role extends beyond production to encompass reducing food waste along the entire supply chain. By leveraging technology and innovation, businesses can optimize resource utilization, minimize post-harvest losses and ensure that existing food resources are efficiently allocated to meet global nutritional needs. For consumers and food retailers alike, reducing food waste not only bolsters food security but also promotes sustainability and resilience in the face of mounting environmental challenges.



## Accessible financial risk management solutions

	Resilience	Response	Recovery	Target systemic driver	Primary	Secondary	Amplifier
<b>Intervention type</b>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Livelihood disruption/ financial loss	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

Financial loss is a significant consequence of climate change, perpetuating broader challenges such as social inequality and food insecurity, which in turn cause or contribute to health-related problems. Despite the growing need for financial protection, traditional indemnity-based agricultural insurance faces challenges such as adverse selection, moral hazard and high costs of loss assessment, making premiums unaffordable for many residents in disaster-prone areas. In Europe, only around a quarter of total economic losses caused by extreme weather events is insured, leaving a substantial protection gap. This is likely to be even wider in low-income countries.<sup>129</sup>

Expanding access to financial risk management solutions is pivotal for addressing both resilience and recovery needs. By offering financial protection, these solutions safeguard the interests of those affected by climate events and provide a crucial lifeline for recovery efforts. Moreover, they incentivize proactive measures for climate-related risk prevention, thus fostering greater resilience within vulnerable communities. The insurance

industry plays a vital role in this endeavour by developing innovative products tailored to the needs of these communities, bolstering their ability to withstand and recover from the impacts of climate change.

Index insurance (or parametric insurance), for instance, offers an objective approach, paying out benefits based on pre-determined factors such as rainfall levels or temperature. This approach mitigates adverse selection and moral hazards, enhances affordability and streamlines claims verification and payout processes. However, challenges such as limited customer awareness and a lack of quality data hinder the scalability of innovative insurance products.<sup>130</sup> Partnerships between insurers, data providers, technology developers, media and regulators are essential to improve product design and drive larger scale adoption. Coordination between the public and private sectors, through initiatives like mitigation investment projects or re-insurance systems, could help limit insurance premiums in vulnerable regions.

## Scientific research

	Resilience	Response	Recovery	Target systemic driver	Primary	Secondary	Amplifier
<b>Intervention type</b>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Scientific knowledge gaps	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
				Change in vector ecology	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Several of the priority topics identified in this analysis involve biological pathways or mechanisms that are not currently well understood. For example, the mechanisms by which pesticides cause hormonal disruption or how allergies correlate with cardiovascular disease remain unclear. A deeper understanding of the underlying biological mechanisms is essential to develop more effective prevention, treatment and management strategies. Furthermore, with the expansion of the geographical range of vectors like mosquitoes and ticks into warmer and more humid environments, and the potential exacerbation of insecticide

resistance driven by new selection pressures due to climate change, there is a pressing need for research in regions most susceptible to emerging infectious diseases and developing novel vector-control solutions.

Collaboration between the life sciences industry, academia and scientific organizations is crucial. By pooling resources and expertise, further research initiatives can be conducted to elucidate causes and develop innovative solutions to mitigate the health impacts of climate change.

# Conclusion

Climate change exerts a multifaceted impact on health, manifesting as extreme weather events, deterioration in air quality, disruptions in food and water availability and quality, heightened risks of food and water contamination, and shifts in infectious agent behaviour and spread. These factors are deeply interconnected, creating a complex web of health challenges. Health impacts can be direct, through the exacerbation of diseases, or indirect through socio-economic factors and limitations in healthcare access, further magnifying the vulnerability of already marginalized populations.

The profound impact of climate change on global health necessitates concerted efforts to build resilient healthcare systems. The private sector plays a crucial role, given its specialist expertise, financial resources and nimbleness. Proactive involvement from the private sector is essential, considering the inevitable impact of climate change on business operations and on employee productivity and well-being.

However, it is critical to recognize that the private sector cannot act in isolation. Cross-industry and cross-sector partnerships, involving the public sector, NGOs, philanthropic organizations and academia, are vital for driving research, policy changes, community engagement and evidence-based decision-making.

The most vulnerable populations include women, particularly those who are pregnant, children, the elderly, and individuals residing in rural and disaster-prone areas and in LMICs. Often, these populations overlap, emphasizing the urgency of interventions targeted at these groups. Current research is lacking in countries with the highest climate risk, especially in Africa and South America. Further research should be conducted to determine how interventions can most effectively reach and benefit these vulnerable populations.

When considering the impact of climate change on health, it becomes evident that certain health areas are more affected than others and the level of current research and actionable guidance varies. Therefore, it is crucial to focus further research and investment on areas where knowledge gaps exist, ensuring that interventions are evidence-based and tailored to address specific health challenges.

Through a comprehensive literature review and evidence assessment, this report identifies 22 priority topics spanning 10 key health areas that demand urgent attention and concerted action. Notably, while some areas are well-researched but still require ongoing efforts, critical gaps in guidance exist in areas such as pregnancy, displacement and migration, highlighting the need for focused attention and intervention.

A causal chain analysis highlighted six key thematic areas for intervention to mitigate a wide range of health consequences of climate change. These interventions primarily focus on building resilience and fortifying healthcare systems to help communities face the challenges posed by climate change.

By fostering collaboration and harnessing the unique capabilities of the private and public sectors, as well as non-profits and research organizations, it is possible to drive strategic investments and initiatives in the priority areas highlighted by the analysis. By acting decisively now, stakeholders can proactively safeguard human health and build a future where societies are more resilient and better equipped to thrive amid the growing challenges posed by climate change.

# Appendix

## A.1 Definition of climate change manifestations and sub-themes

<b>Extreme weather</b>	Extreme temperatures	Climate change is increasing the frequency, intensity and duration of heatwaves; heat-related risk is set to increase due to the greenhouse gases already in the atmosphere that are rapidly warming the Earth's climate.
	Wildfires	Hotter and drier conditions caused by climate change are resulting in bigger, more frequent and longer-lasting wildfires.
	Heavy rainfall, flooding	An increase in global temperatures leads to both higher snowmelt rates and an increase in precipitation intensity, duration and/or frequency, which trigger floods.
	Droughts	Prolonged dry periods in the natural climate cycle due to rise in temperature, soil erosion and water scarcity cause droughts.
	Storms and hurricanes	Atmospheric disturbance marked by wind and dust, rain, snow, hail, or thunder and lightning is increasing due to an increase in global warming, sea-level rise, coastal erosion etc.
	Geological hazards	Climate change can intensify geological hazards like earthquakes and tsunamis through factors such as sea-level rise, altered precipitation patterns and melting glaciers.
<b>Air quality</b>	Higher concentration of allergens and pollen	Warmer temperatures and increased CO <sub>2</sub> concentrations favour pollen release and higher pollen counts. Warmer temperatures also extend the growing season of many plants.
	Higher air pollutant (e.g. CO, SO <sub>x</sub> , NO <sub>x</sub> , O <sub>3</sub> ) concentration	Air containing dust, smoke and microorganisms, or gases different from those that it would normally be composed of. Climate change can impact air pollutant concentrations through its effects on meteorological variables.
<b>Food and water risks</b>	Food and water security and quality	Changes in land and sea due to climate change reduce the availability, accessibility (economically and physically) and quality of water and food.
		Climate change may increase human exposure to dangerous chemicals in several ways, as more frequent and intense extreme weather results in chemicals being released into the air, water and food systems.
<b>Infectious agents</b>	Vector-borne	Climate change can expand the geographic range of disease vectors and prolong the breeding seasons of, e.g. malaria, dengue and chikungunya.
	Waterborne and food-borne	Changes in precipitation patterns, temperature and ecological conditions lead to changes in water quality and food production causing outbreaks of diseases such as cholera, Hepatitis A and salmonella.
	Airborne	Climate change can influence the occurrence and transmission of airborne epidemics by altering temperature and humidity patterns, affecting the survival and distribution of airborne pathogens, causing, e.g. influenza, tuberculosis and measles.
	Direct contact	Climatic hazards move people closer to pathogens and improve the climate suitability for the reproduction and acceleration of pathogens' life cycles, thereby increasing the length of exposure – COVID, Ebola and methicillin-resistant staphylococcus aureus (MRSA) are some examples.

## A.2 | Health areas categorization

Direct health outcome groups	WHO ICD-11 categories included
<b>Immune system/infectious diseases</b>	01 Diseases of the immune system 04 Certain infectious or parasitic diseases
<b>Neoplasms</b>	02 Neoplasms (abnormal mass of tissue)
<b>Blood</b>	03 Diseases of the blood or blood-forming organs
<b>Nutritional and metabolic diseases</b>	05 Endocrine, nutritional or metabolic diseases
<b>Neurodevelopment and mental health</b>	06 Mental, behavioural or neurodevelopmental disorders 07 Sleep-wake disorders 08 Diseases of the nervous system
<b>Visual system</b>	09 Diseases of the visual system
<b>Ear and mastoid process</b>	10 Diseases of the ear or mastoid process
<b>Circulatory system</b>	11 Diseases of the circulatory system
<b>Respiratory system</b>	12 Diseases of the respiratory system
<b>Digestive system</b>	13 Diseases of the digestive system
<b>Skin</b>	14 Diseases of the skin
<b>Musculoskeletal system</b>	15 Diseases of the musculoskeletal system or connective tissue
<b>Genitourinary</b>	16 Diseases of the genitourinary system 17 Conditions related to sexual health
<b>Pregnancy</b>	18 Pregnancy, childbirth or the puerperium 19 Certain conditions originating in the perinatal period
<b>Injury and external causes</b>	22 Injury 23 External causes of mortality

**Note:** Categories 20-21 and 24-26 were evaluated as irrelevant and not included: 20 Developmental anomalies; 21 Symptoms, signs or clinical findings, not elsewhere classified; 24 Factors influencing health status or contact with health services; 25 Codes for special purposes, 26 Supplementary Chapter Traditional Medicine Conditions.



Indirect health determinants	Definition
<b>Social impact</b>	<ul style="list-style-type: none"> <li>– Decrease in quality of life: The WHO defines Quality of Life as an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns.</li> <li>– Decrease in community health: Increased interpersonal aggression, violence and crime, decreased community cohesion, etc.</li> <li>– Increase in social inequality/vulnerability: Greater exposure to climate hazards, greater susceptibility to damages caused by climate hazards, less ability to cope with and recover from the damages caused by climate hazards.</li> </ul>
<b>Economic impact</b>	<ul style="list-style-type: none"> <li>– Personal economic loss: Additional expenses, loss of job or capacity to work, loss of assets, etc.</li> <li>– Broader economic impact: Impact on factors such as inflation, increased unemployment, lower labour productivity, higher healthcare burden etc.</li> </ul>
<b>Displacement and migration</b>	<ul style="list-style-type: none"> <li>– Displacement: Loss or damage of shelter/housing (e.g. indoor damages that make homes inhabitable or cause health problems).</li> <li>– Involuntary migration: Involuntary internal and external migration among the communities impacted.</li> </ul>
<b>Health system and infrastructure</b>	<ul style="list-style-type: none"> <li>– Healthcare infrastructures disruption: Damage to healthcare infrastructure, limited access or overcrowding, limited access to preventative measures (e.g. routine immunizations).</li> <li>– Disruptions to health systems: Significant interruptions or breakdowns within the processes or functioning of healthcare systems, including supply chain disruptions and reduction in availability of critical medicines or medical devices, technological failures, etc.</li> </ul>
<b>R&amp;D impact</b>	<ul style="list-style-type: none"> <li>– R&amp;D impact: Limitations to research and development (including technology, e.g. loss of biodiversity that may impact drug development).</li> </ul>

## A.3 Methodology for assessment of the impact of climate change on health

### Scoring methodology

A scoring system was developed to evaluate each intersection in the matrix.

- For the 15 direct health outcome groups, the impact of climate change was assessed by:
  1. The likelihood of the health impact occurring on an individual.
  2. The severity of the impact.

- For the 10 indirect health determinants, the impact of climate change was assessed by:





1. The likelihood of the health impact occurring for majority of the population.
2. The recovery time needed to mitigate the impact.

The evaluation utilized a 5-point scale to score each intersection according to the following criteria, with intersections scored 4 or 5 classified as high-impact intersections:

Impact score	Impact score criteria	
	Direct health impact area	Indirect health impact area
5	High likelihood and high severity	High likelihood and long recovery time
4	Moderate/low likelihood and high severity	Moderate/low likelihood and long recovery time
3	Moderate likelihood and/or severity	Moderate likelihood and/or medium recovery time
2	High likelihood and low severity	High likelihood and short recovery time
1	Unlikely or lack of evidence	Unlikely or lack of evidence

Results of the scoring assessment are summarized below.

FIGURE 14 Detailed scoring results

	 Extreme weather						 Air quality		 Food and water risks				 Vector ecology			
	Heavy rainfall and flooding	Drought	Wildfires	Extreme temperatures	Storms and hurricanes	Geological hazards	Allergens and pollen	Air pollutants	Water quality	Water security	Food quality	Food security	Vector-borne	Food- and waterborne	Airborne	Direct contact
<b>Direct health outcome groups</b>																
Immune	5	2	4	3	5	4	1	3	5	5	5	5	5	5	5	5
Neoplasms	0	2	4	0	3	0	0	5	4	0	4	0	3	0	0	0
Blood	3	3	0	0	2	3	0	2	3	0	1	3	4	3	2	3
Metabolic/nutritional	5	5	3	1	3	4	2	0	4	4	4	4	2	3	0	0
Mental health	5	5	5	5	5	5	3	4	4	4	4	4	3	3	4	5
Visual	2	1	4	3	2	2	3	3	3	2	2	2	2	1	2	1
Ear/mastoid process	2	0	1	1	2	1	1	1	3	0	0	2	1	1	1	0
Circulatory	4	3	4	5	4	4	4	5	2	4	0	4	5	2	3	0
Respiratory system	3	3	5	5	4	4	5	5	3	3	0	3	3	0	5	4
Digestive system	3	4	3	1	3	3	1	3	5	5	5	5	2	5	2	4
Skin	3	1	4	3	2	2	3	3	2	1	0	2	2	1	2	4
Musculoskeletal	3	0	2	3	1	2	1	2	4	3	3	4	3	3	2	3
Genitourinary	2	2	2	3	0	3	1	2	4	3	3	3	3	4	3	2
Pregnancy	4	3	4	4	4	4	1	2	4	4	4	4	4	4	4	4
Injury	4	0	4	4	4	4	0	0	4	3	4	3	3	3	0	3
<b>Indirect health determinants</b>																
Social inequality	5	5	5	5	5	5	3	5	5	5	5	5	5	5	5	5
Quality of life	5	5	5	5	5	5	3	3	5	5	5	5	4	4	4	4
Community health	3	3	3	4	3	3	0	0	4	4	4	4	4	4	4	4
Personal financial loss	4	4	5	3	4	4	3	3	3	5	2	3	4	4	3	4
Broader economic situation	3	4	3	3	4	4	1	4	5	5	4	5	3	3	4	4
Housing damage/loss	4	2	4	2	4	4	0	2	0	0	0	0	0	0	0	0
Involuntary migration	5	5	5	4	5	5	0	1	2	5	2	5	0	5	4	5
Health systems disruption	4	4	4	3	4	4	0	2	3	3	3	3	0	0	0	0
Healthcare infrastructure damage	4	3	4	3	4	4	1	1	5	5	5	5	5	5	5	5
Research and development	4	4	4	4	4	4	0	3	0	2	0	1	4	4	4	4

 High-impact intersections

## Sources

Approximately 350 sources from academic literature and resources published by various organizations were evaluated to complete the scoring assessment.

### Literature

Adami et al. (2021)	Cervellati et al. (2022)	Gezer et al. (2020)
Agbeko et al. (2022)	Chan et al. (2023)	Goto et al. (2004)
Aggarwal et al. (2019)	Charnley et al. (2022)	Gruffydd-Jones et al. (2019)
Aitken et al. (2022)	Charnley et al. (2021)	Gundersen et al. (2015)
Akciğer et al. (2023)	Chen et al. (2019)	Guo et al. (2022)
Alao et al. (2021)	Chen et al. (2021)	Gupta et al. (2021)
Andreae et al. (2022)	Cherry et al. (2010)	HabibiSaravi et al. (2021)
Ariya et al. (2021)	Cheu et al. (2019)	Hader et al. (2007)
Aryal et al. (2022)	Choudhury et al. (2022)	Hamanaka et al. (2018)
Babaie et al. (2021)	Clark et al. (2016)	Hanmer et al. (2021)
Baird et al. (2022)	Courville et al. (2022)	Hatcher et al. (2022)
Baldacci et al. (2015)	Currie et al. (2013)	He et al. (2019)
Basili et al. (2014)	D'Amato et al. (2020)	Hennessy et al. (2008)
Bawden (2022)	Darbre et al. (2018)	Hewings-Martin (2019)
Bazoukis et al. (2018)	Dasaradhan et al. (2022)	Hoang-Thi et al. (2022)
Bergmann et al. (2011)	Davis et al. (2022)	Huang et al. (2011)
Berman et al. (2021)	Davis et al. (2018)	Huang et al. (2016)
Beyene et al. (2023)	Desai et al. (2020)	Huang et al. (2022)
Bhandari et al. (2023)	Dierick et al. (2020)	Ibanez et al. (2021)
Bhaskar et al. (2018)	Dong et al. (2014)	Jamshidi et al. (2022)
Bladacci et al. (2015)	Doocy et al. (2013)	Jandale et al. (2022)
Bortel et al. (2016)	Drewnowski et al. (2022)	Javelle et al. (2014)
Brooks et al. (2019)	Echevarría-Lucas et al. (2021)	Joseph et al. (2023)
Broyles et al. (2017)	Elmes et al. (2016)	Kampe et al. (2016)
Burrows et al. (2023)	Elson et al. (2020)	Kang et al. (2015)
Canonica et al. (2008)	Fadadu et al. (2021)	Katona et al. (2008)
Cappelli et al. (2021)	Findlater et al. (2018)	Kim et al. (2022)
Ceferino et al. (2020)	Gaskins et al. (2020)	Kirolos et al.
	Geere et al. (2018)	

Kolli et al. (2022)	Lunt and Heenan 2019	Nola et al. (2018)
Kumar et al. (2018)	Maglio et al. (2016)	Norman et al. (2021)
Kunze et al. (2021)	Manan et al. (2018)	Papanikolaou et al. (2012)
Kušević et al. (2021)	Marcondes et al. (2019)	Papapostolou et al. (2021)
Landeg et al. (2019)	Margas et al. (2022)	Parker et al. (2022)
Leary et al. (2022)	Mavrouli et al. (2021)	Parker et al. (2022)
Lee et al. (2006)	Mavrouli et al. (2023)	Parsons et al. (2022)
Lee et al. (2019)	McAllister et al. (2019)	Partash et al. (2022)
Lee et al. (2022)	Meaney-Delman et al. (2013)	Pradhan et al. (2017)
Leiman et al. (2022)	Melillo et al. (2020)	Quinn et al. (2014)
Lempert et al. (2013)	Melilo et al. (2020)	Quist et al. (2021)
Leonard et al. (2017)	Mendes et al. (2021)	Rather et al. (2017)
Lerentz (2022)	Mesrkanlou et al. (2022)	Raut et al. (2021)
Lim et al. (2019)	Mikula et al. (2021)	Ravimohan et al. (2018)
Lin et al. (2021)	Miranda (2022)	Rehman et al. (2019)
Lin et al. (2022) Lindvall et al. (2020)	Mitra et al. (2018)	Rezaeian et al. (2013)
Liu et al. (2021)	Miwa et al. (2021)	Ribeiro et al. (2015)
Lombard et al. (2021)	Miyazaki et al. (2019)	Roberts et al. (2021)
Lukina et al. (2021)	Modenese et al. (2018)	Robin et al. (2020)
Lukwa et al. (2020)	Moradi et al. (2018)	Ross et al. (2022)
Lunt et al. (2019)	Moulds et al. (2021)	Tsuboyama-Kasaoka (2014)
	Nogueira et al. (2020)	

## Corporate, international and academic organizations

Airly	CEPR
Allergy and Asthma Clinic of Fort Worth	Cervest
Allergy and Asthma Network	Chronicle
American Academy of Dermatology Association	Citymed
American Association for Cancer Research	Clay Centre
American Association of Pharmaceutical Researchers and Innovators	Clemson University
American Heart Association	Climate Health
American Lung Association	Climate Migration Coalition
American National Standards Institute	CNN
American Pregnancy Association	Conserve Energy Future
American Psychiatric Association	Council on Foreign Relations
Aqua Medix	Country Health Rankings
Arkansas Urology	Diabetes Quebec
Asthma and Allergy Foundation of America	Dismuke Law
Axios	Drought.gov
Barraquer	Duke Health
British Broadcasting Corporation (BBC)	Earth.com
Beyond Pesticides	European Environment Agency (EEA)
BJC Healthcare	Environmental Health Perspectives (EHP)
Boston University	Endocrine web
Boulder county	Environmental Protection Agency (EPA)
Breeze Technologies	Eurofund
British Assessment Bureau	European Geosciences Union
British Heart Foundation	Food and Agriculture Organization (FAO)
Brookings	Free Drinking Water
British Society for Allergy and Clinical Immunology	GitHub
Boston University School of Public Health	Global Hunger Index
Cancer.gov	Global Risk Insights
CBS	Global Thinkers Forum
Centers for Disease Control and Prevention (CDC)	Global Panel on Agriculture and Food Systems for Nutrition (GLOPAN)
Centrick	Go Pure

GoHealth	Medical News Today
Government of Ontario (Govt. of Ontario)	MedicineNet
Grantham Institute	Melio
Harvard University (Harvard Edu)	Memorial Village
Healio	Minnesota Department of Health
Health Central	MOAS
Healthline	Mora Lab, University of Hawaii
Healthychildren.org	MSD
Hearing Health Foundation	Mylo Family
Heart.org	National Aeronautics and Space Administration (NASA)
International Labour Organization (ILO)	National Geographic
International Monetary Fund (IMF)	National Bureau of Economic Research
Imperial Hearing	National Centers for Environmental Information
inBalance	National Health Service (NHS)
iNews UK	National Institute for Health and Care Excellence
Internal Displacement Monitoring Centre	National Institutes of Health (NIH)
Internal Displacement Organization	National Public Radio
International Organization for Migration (IOM)	Nutra Ingredients USA
IOM UN Migration	Nvision
Intergovernmental Panel on Climate Change (IPCC)	Office of the Assistant Secretary for Health (OASH)
Irving Medical Centre	Organisation for Economic Co-operation and Development (OECD)
ISDC	Oncology Nurse Advisor
Institute for Strategy, Resilience and Security (ISID) Johns Hopkins University (Johns Hopkins)	Office for National Statistics (ONS)
Kidney.org	ONS Voice
King's College London	Oregon University
LG SONIC	Pacific Standard
Link	Patient UK
Live Science	Prevention Web
Lung.org	PROOF
Mayo Clinic	Queen's University
McGill University	Redwood Orthopaedic
Medical Care	Relief Web

Reuters	United Nations Convention to Combat Desertification
Review of Optometry	Understanding Floods Queensland Government
Substance Abuse and Mental Health Services Administration (SAMSHA)	United Nations Environment Programme (UNEP)
Save the Children	United Nations Population Fund (UNFPA)
Science Daily	United Nations Children's Fund (UNICEF)
Senate.gov	United Nations University
Skin Cancer Foundation	University of New Hampshire
St. Edmund Eye Hospital	United States Senate (US Senate)
State of Global Air	United States Environmental Protection Agency
Society for Urban, Ecology and Restoration (SUERF)	Verisk
Texas Extension Disaster Education Network	WaterAid.org
The Fuller Project	Well Right
The Water Project	Wellcome
Think Global Health	World Health Organization (WHO)
Tracie Healthcare	World Intellectual Property Organization (WIPO)
Tulsa Endoscopy Center	Wise Family Eye Center
University of California, Los Angeles (UCLA)	World Meteorological Organization (WMO)
UCLA Health	World Bank
United Nations (UN)	World Resources Institute (WRI)
Unacademy	World Vision
University of North Carolina (UNC)	World Wide Fund for Nature (WWF)
	Yale University



## A.4 Evidence quantification methodology

### Objective

The objective of the web-scraping analysis was to evaluate the evidence landscape concerning the intersection of climate and health. This evaluation focuses solely on publicly available, English

language-only resources, encompassing academic literature and resources from credible organizations active in the climate and health space.

### Tools and technologies

The web-scrape included two English-based academic databases – PubMed and the National Institute of Environmental Health Sciences (NIEHS). These databases were selected to assess academic literature on climate and health, supported by key reports from institutional websites.

Two types of web-scraping tools were employed for this analysis:

- A scraper developed in-house by L.E.K., tailored to the academic databases (i.e. PubMed and NIEHS).
- ParseHub, an online data extraction tool, for scraping institutional sites.

### Data selection

Data collected included the title, abstract (for academic articles), publishing date, author and source of each article scraped. Inclusion criteria for articles scraped included:

- Climate relevance
  - PubMed: A list of 10 to 20 keywords for each climate change sub-theme and each direct and indirect health impact area was developed. For PubMed, the presence of the keywords was checked within the abstract or the first 1,000 words of each article.

- NIEHS: Assessments, books, reviews, reports and research articles from the “climate change and human health literature portal” were included.

- Timeframe: Articles published between 2018 and 2023.

With the above inclusion criteria, the search initially yielded 42,000 web-based articles in total across the three sources.

### Keywords: Climate change manifestations and sub-themes

Climate change manifestation	Sub-theme	Keywords used
	Heavy rainfall, flooding	Rainfall OR “fluvial flood” OR flood rainfall OR pluvial OR “heavy rain”
	Drought	Drought OR aridity OR “dry spell” OR precipitation deficit OR arid OR desert OR droughts
	Wildfires	Wildfires OR “forest fires” OR bushfires OR “fire outbreaks” OR “fire ecology” OR “fire behavior”
Extreme weather	Extreme temperatures	“Extreme temperatures” OR “heat waves” OR “heat stress” OR “temperature records” OR “high temperatures” OR heatwave OR “extreme heat”
	Storms and hurricanes	Storms OR “severe storms” OR thunderstorms OR hailstorms OR windstorms OR cyclones OR blizzards OR “dust storm” OR “storm surge”
	Geological hazards	“Geological hazards” OR earthquake OR tsunamis OR “volcanic eruptions” OR “seismic activity” OR “tectonic events” OR volcano OR seismic

<b>Air quality</b>	Allergens and pollen	("climate") AND (Allergy OR allergens OR allergic OR allergies OR allergen OR anaphylaxis OR pollen OR "allergy season" OR "biological allergens")
	Air pollutants	("climate")AND ("Ground level ozone" OR "particulate matter" OR "carbon dioxide" OR "CO <sub>2</sub> " OR "carbon monoxide" OR "SOx" OR "Sulfur oxide" OR "Sulphur Oxide" OR "Nitrous Oxide" OR NOx OR NO2 OR "Ozone pollution" OR "Tropospheric ozone" OR "ozone exposure" OR "ozone smog" OR "PM10" OR "PM2.5" OR "particulate monitoring" OR "air pollution" OR "air pollutants" OR "particulate pollution" OR "Nitrogen dioxide" OR "Sulfur dioxide" OR "carbon monoxide" OR "volatile organic compounds" OR "Polycyclic Aromatic Hydrocarbons" OR "Ammonia gas"
<b>Food and water risks</b>	Water quality	("climate")AND ("Water systems" OR "Contaminated water" OR "poor sanitation" OR "inadequate sanitation" OR "sanitation" OR "drinking water" OR "safe drinking water" OR "water contaminants" OR "water contaminated" OR "bathing water" OR "polluted water" OR "water pollution" OR "water contamination" OR "water contam*" OR "water quality" OR "clean water" OR "dirty water" OR "water treatment" OR "Water testing" OR "Water standards" OR "Water purification" OR "Water filtration" OR "Chlorination" OR "Water disinfection"
	Water security	("climate")AND ("Accessibility of water" OR "water security" OR "water scarcity" OR "water access" OR "access to water" OR "water stress" OR "inadequate water" OR "water supply" OR "water insecurity" OR "scarcity of water" OR hypohydration OR "lack of water" OR "available water" OR "water availability" OR "water outage" OR "inaccessible water sources" OR "chronic dehydration" OR "recurrent dehydration" OR "water shortage" OR "water collection" OR "access to drinking water" OR "water deficit" OR "Water infrastructure" OR "Water management" OR "Water conservation" OR "Water policy" OR "Water allocation" OR "Water governance" OR "Water rights" OR "Water supply management" OR "Water resource management" OR "Water crisis" OR "Water resilience"
	Food quality	("climate")AND ("organic pollutant" OR "food contamination" OR "unsafe food" OR "contaminants in food" OR "aflatoxin" OR "biphenyls" OR "disinfection by-products" OR "pesticides" OR "prions" OR "metal contamination" OR "botulism" OR "chemicals in food" OR "contaminated food" OR "nutrient deficiencies" OR "chemical contamination" OR "nutrients" OR "nutrition" OR "food quality" OR "quality food" OR "poor diet" OR "diet" OR "Food safety" OR "Food inspection" OR "Food handling" OR "Food regulations", "Food quality control" OR "Food contamination sources"
	Food security	("climate")AND ("food security" OR "food insecurity" OR "agricultural production" OR "crop yield" OR "food availability" OR "food access" OR "food stability" OR "food-secure" OR "food-insecure" OR "access to food" OR "availability of food" OR "food insecu*" OR "food secur*" OR "food poverty" OR "Food distribution" OR "Food supply" OR "Food assistance program" OR "Food production" OR "Food imports" OR "Food export" OR "Food price volatility" OR "Food aid" OR "Food resilience"
<b>Infectious agents</b>	Vector-borne	("climate")AND ("Disease vector" OR "vector-borne" OR "malaria" OR "dengue" OR "chikungunya" OR "zika" OR "West Nile fever" OR "Yellow fever" OR "Lyme Disease" OR "West Nile Virus" OR Leishmaniasis OR Typhus OR "Rocky Mountain Spotted" OR "Chagas Disease" OR "African Trypanosomiasis" OR "Japanese Encephalitis" OR "Rift Valley Fever" OR "Crimean-Congo Hemorrhagic" OR "vector biting" OR "mosquito" OR "Chagas disease" OR "VBD" OR "vector borne"
	Food and water borne	("climate")AND ("Waterborne disease" OR "food-borne illness" OR "foodborne infections" OR "foodborne illness" OR "foodborne illness" OR "Foodborne outbreak" OR "Foodborne pathogen" OR "Foodborne bacteria" OR "water-borne illness" OR "waterborne infection" OR "waterborne illness" OR "waterborne illness" OR "waterborne outbreak" OR "waterborne pathogen" OR "waterborne bacteria" OR "cholera" OR "Salmonella" OR "Hepatitis A" OR "water-borne disease" OR "food-borne disease" OR "foodborne disease" OR "Salmonellosis" OR "Campylobacteriosis" OR "E. coli" OR "Listeriosis" OR "Norovirus" OR Giardiasis OR Shigellosis OR Botulism OR Rotavirus OR Cryptosporidiosis OR Vibrio OR Cyclosporiasis OR Trichinosis OR Amoebiasis OR Brucellosis OR Toxoplasmosis OR Clostridium perfringens OR "Staphylococcal food poisoning" OR "gastroenteritis" OR "Waterborne pathogen"
	Air-borne	("climate")AND ("airborne epidemics" OR "airborne pathogens" OR "TB" OR "tuberculosis" OR "measles" OR "Influenza" OR "Whooping cough" OR "air-borne illness" OR "airborne illness" OR "air-borne pathogens" OR "airborne pathogens" OR "air-borne disease" OR "airborne disease" OR "air borne disease" OR "air borne illness" OR "air borne pathogens" OR "air-borne infect*" OR "airborne infect*" OR "air borne infect*"
	Direct contact	("climate") AND ("Direct contact epidemic" OR "direct contact pandemic" OR "Ebola" OR "MRSA" OR "direct contact infections" OR "direct contact diseases" OR "Anthrax" OR "covid" OR "chlamydia" OR chickenpox OR varicella OR herpes OR ringworm OR impetigo OR scabies OR Molluscum Contagiosum OR syphilis OR "hand OR foot and mouth disease" OR chancroid OR gonorrhoea OR "granuloma inguinale" OR "mycobacterium marinum" OR Tuberculosis OR Streptococcal OR meningococcal OR staphylococcal OR coronavirus

## Keywords: Direct health outcome groups

Health area	Keywords used
<b>Immune system</b>	Immune OR autoimmune OR immunodeficiency OR allergy OR inflammation OR infectious OR parasitic OR infection OR viral OR virus
<b>Neoplasms</b>	Neoplasms OR tumor OR cancer OR malignant OR benign OR metastasis OR carcinogen
<b>Blood or blood-forming organs</b>	"Blood diseases" OR hematologic OR anemia OR "bleeding disorders" OR coagulation OR "blood cancers" OR hemophilia OR hemophilia OR hematologic OR neoplasms OR leukemia OR lymphoma OR myeloma OR "blood forming organ"
<b>Nutritional and metabolic diseases</b>	endocrine OR hormonal OR diabetes OR thyroid OR metabolic OR nutritional OR obesity OR malnutrition OR obesity OR diabetes OR undernutrition OR metabolism
<b>Neurodevelopment and mental health</b>	Mental OR mental OR psychiatric OR mood OR anxiety OR neurodevelopmental OR "autism spectrum" OR Sleep-wake OR "sleep disorder" OR insomnia OR "sleep apnea" OR narcolepsy OR "circadian rhythm" OR "nervous system" OR neurological OR neurodegenerative OR epilepsy OR "multiple sclerosis" OR "Parkinson's" OR "Alzheimer's" OR depression OR suicide OR "PTSD" OR neurological OR "nervous system"
<b>Visual system</b>	"Eye disease" OR cataracts OR glaucoma OR "macular degeneration" OR ophthalmology OR ophthalmologists OR "eye inflammation" OR "eye irritation" OR "dry eyes" OR "eye damage" OR "visual system"
<b>Ear and mastoid process</b>	"Ear diseases" OR "hearing disorder" OR "otitis media" OR "otitis externa" OR tinnitus OR audiology OR "hearing loss" OR audiologists OR mastoid OR "balance loss"
<b>Circulatory system</b>	circulatory OR cardiovascular OR "heart disease" OR hypertension OR coronary artery OR stroke OR "heart failure" OR arrhythmias OR vascular OR CVD OR ischemic OR tachycardia OR "myocardial infarction" OR "atrial fibrillation" OR "heart attack"
<b>Respiratory system</b>	"Respiratory disease" OR "lung disease" OR asthma OR "chronic obstructive pulmonary disease" OR COPD OR pneumonia OR bronchitis OR pulmonary OR "respiratory infection" OR "lung function" OR "respiratory system" OR "airways inflammation"
<b>Digestive system</b>	"Digestive system" OR gastrointestinal OR digestive OR gastroenteritis OR "irritable bowel syndrome" OR bowel OR IBS OR "inflammatory bowel disease" OR liver OR pancreatitis OR diarrhoea OR gastroenteritis OR "abdominal pain" OR "GI symptoms"
<b>Skin diseases</b>	skin OR dermatological OR "skin disorders" OR eczema OR psoriasis OR acne OR dermatitis OR dermatology OR "skin disease"
<b>Musculoskeletal system</b>	"Musculoskeletal system" OR "connective tissue" OR "musculoskeletal disorders" OR "bone diseases" OR "joint diseases" OR arthritis OR osteoporosis OR "muscular dystrophy" OR fibromyalgia OR "bone density"
<b>Sexual health</b>	"Genitourinary system" OR "sexual health" OR "genitourinary diseases" OR "urologic disorders" OR "kidney" OR "urinary tract infections" OR "UTI" OR "sexual dysfunction" OR "sexually transmitted infections" OR "STI" OR infertility OR "decline in kidney function"
<b>Pregnancy</b>	"Pregnancy childbirth puerperium" OR "perinatal period" OR obstetric OR maternal OR perinatal OR prenatal OR childbirth OR postpartum OR pregnant OR pregnancy OR childbirth OR "premature birth" OR "low birthweight" OR "impaired fetal growth" OR "birth defect" OR "preterm birth" OR miscarriage OR "fetal loss"
<b>Injury or external causes</b>	Injury OR traumatic OR trauma OR accidents OR poisoning

## Keywords: Indirect health determinants

Health area	Keywords used
Social impact	Increase in social inequality social inequality OR socioeconomic OR "social inequities" OR "social stratification" OR "income inequality" OR "wealth inequality" OR "entrench poverty" OR "vulnerable communities" OR "vulnerable population" OR marginalized OR "ethnic groups" OR "low income"
	Decrease in quality of life "Quality of life decrease" OR "well-being" diminished OR "living conditions" OR "standard of life" OR "quality of life" OR "wellbeing"
	Community health "Community health" OR "public health" OR "community well-being" OR "civil conflict" OR "community conflict" OR crime OR "decreased community cohesion" OR "domestic violence" OR assault
Economic impact	Personal economic loss "Personal finances" OR "financial impact" OR "financial burden" OR "financial hardship" OR "loss of income" OR "household finances" OR "household wealth" OR "personal wealth" OR "job disruption" OR "unable to work" OR "poverty"
	Broader economy impact "Broader economy impact" OR macroeconomic impact OR "economic consequences" OR "economic downturn" OR macroeconomic OR employment rates OR labour shortage OR "low employment rates" OR hyperinflation OR "economic challenges" OR "inflation" OR "GDP" OR "economic shocks"
Displacement and migration	Loss or damage of shelter "Housing damage" OR homeless OR "housing crisis" OR "inadequate housing" OR "housing instability" OR "shelter damage"
	Involuntary migration "Involuntary migration" OR "forced migration" OR "displaced populations" OR "involuntary displacement" OR refugees OR "asylum seekers" OR refugee OR "involuntary migrants" OR "forced migrants"
Infrastructure and services	Disruption to health systems "Disruption to health systems" OR "healthcare system disruption" OR "healthcare service disruption" OR "impact on healthcare delivery" OR healthcare supply chain OR "healthcare service" disruption OR supply disruption healthcare OR "power cuts" OR "power outage"
	Healthcare infrastructures damage or limited access or overcrowding "Healthcare infrastructure" OR "access to healthcare" OR "overcrowding hospitals" OR damage healthcare facilities OR "healthcare access" OR "overcrowded healthcare facilities" OR "hospital damage" OR "limited care delivery" OR "damaged health equipment" OR "damaged medical infrastructure" OR "emergency response" OR "hospital overcrowding" OR hospital wait time OR "health care infrastructure"
R&D	Research and development impact Innovation OR "technological advancement" OR "R&D" OR "healthcare innovation" OR "clinical trial disruption" OR "trial suspension" OR "trial site damage" OR "compromised trial"

## Data cleaning

Data-cleaning filters were applied to the dataset to remove irrelevant evidence. Exclusion filters included:

- Removal of non-human related evidence based on keywords, taking into account keywords required to also exclude articles of irrelevant nature such as articles on clinical trial results ("plant" OR "drug" OR "vitro" OR "therapy" OR "treatment" OR "trial" OR "protein" OR "enzyme" OR "RNA" OR "biochemical" OR "gene" OR "metabolic" OR "cytokine storm" OR "genome").
- Removal of duplicates.

- Removal of evidence not relevant for any high-impact intersections.
- Removal of evidence in the wrong time frame i.e. published before 2018.
- Relevant only to low- and medium-impact intersections.

After applying additional data-cleaning filters, approximately 13,000 unique web-based articles were identified, which yielded approximately 39,000 matches to the high-impact intersections (one article could match to multiple high-impact intersections).

## Data categorization

Geographical distribution of the articles was based on the countries and categorization of region according to the World Bank.

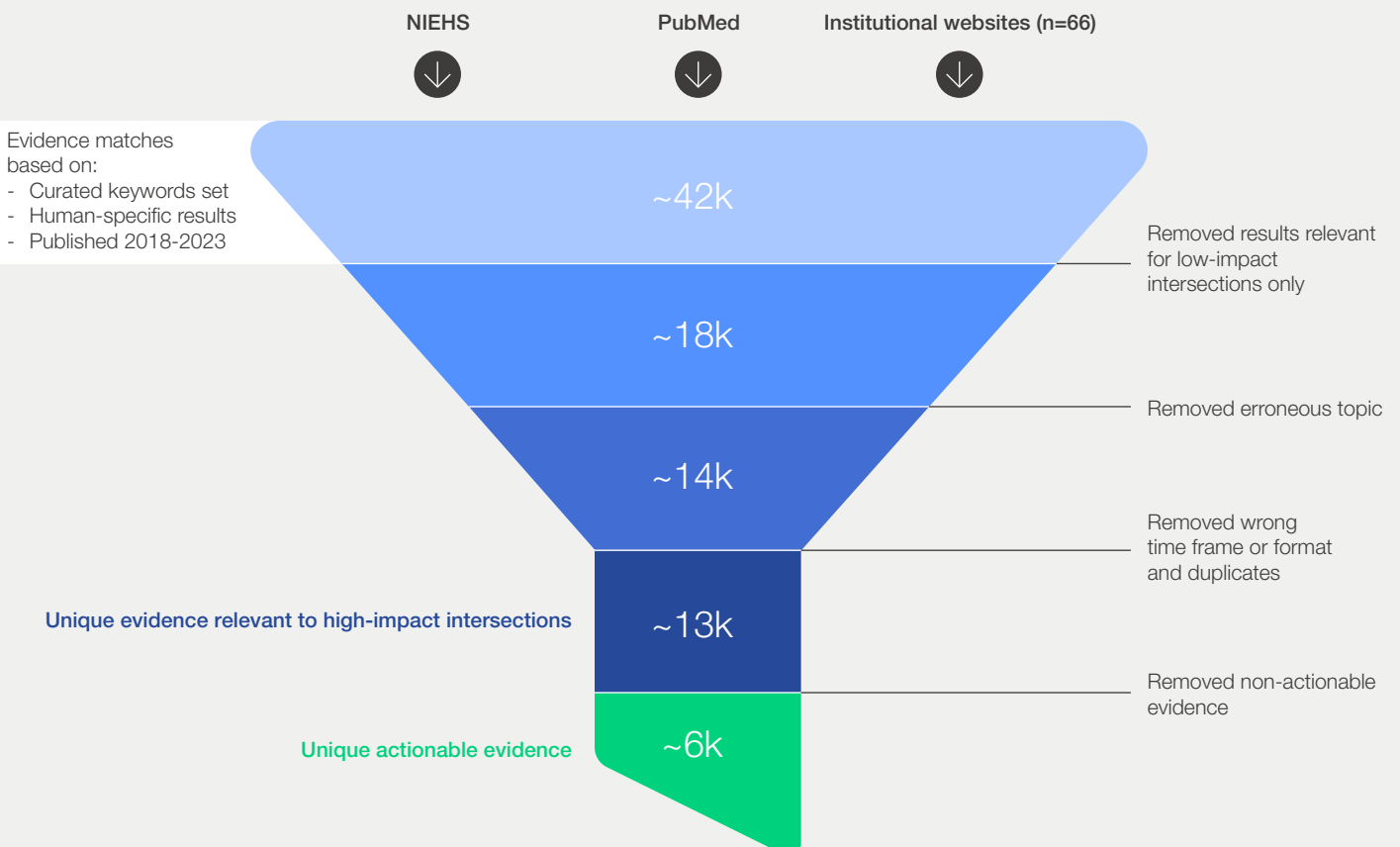
Further categorization of the articles was based on a list of keywords (see table below). Each

keyword and its combination were tested for accuracy. A confidence level of 80% was achieved for categorization as "actionable" when more than 0.1% of the length of the abstract and title consisted of the listed keywords for "actionable".

Category	Keywords used
<b>Actionable evidence availability</b>	Actionable Any grammatical forms of the following words: "actionable" OR "prevent" OR "mitigate" OR "solution" OR "recommend" OR "implement" OR "intervene" OR "protect" OR "assist" OR "plan" OR "serve"
	Non-actionable Any articles without the keywords above
<b>Target stakeholder</b>	Private sector "Private Sector" OR "Business" OR "Aerospace" OR "Agriculture" OR "Food And Beverage" OR "Aviation" OR "Travel" OR "Automotive" OR "Biotechnology" OR "Healthcare" OR "Pharmaceutical" OR "Medtech" OR "Energy Sector" OR "Education" OR "Engineering" OR "Construction" OR "Manufacturing" OR "Financial Services" OR "Insurance" OR "Technology" OR "Logistics" OR "Transportation" OR "Media" OR "Entertainment" OR "Mining" OR "Oil And Gas" OR "Real Estate" OR "Retail" OR "Consumer Service"
	Public sector "Public Sector" OR "Policy" OR "Policymaker" OR "Legislation" OR "Government" OR "Regulator" OR "Federal" OR "Civil Society" OR "Law"

FIGURE 15

Data categorization



## Limitations and mitigation strategies

Limitations to the approach used have been considered and mitigated when feasible as outlined below.

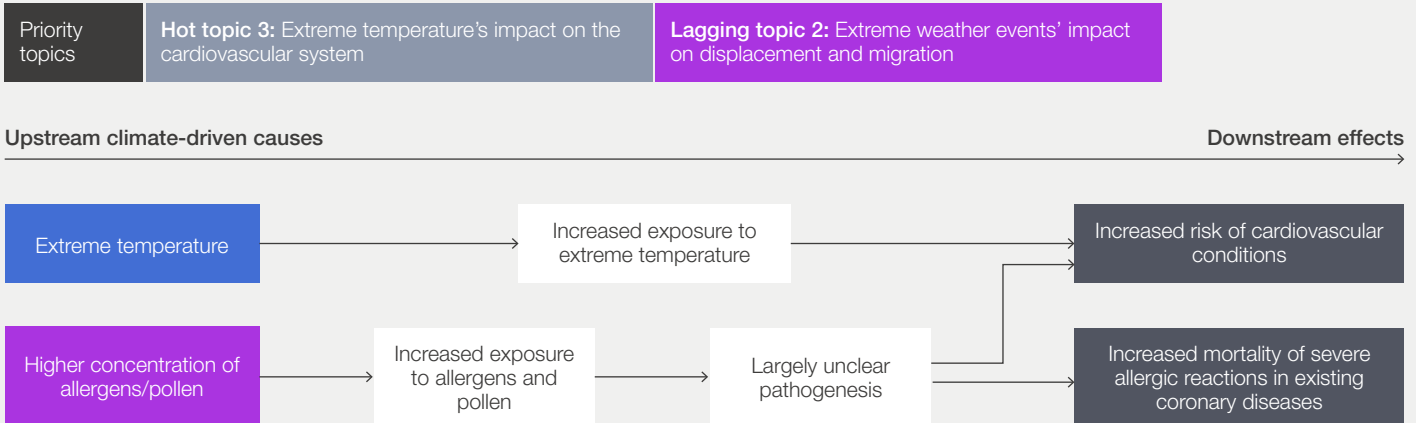
Process	Data challenge	Mitigation approach
<b>Data collection</b>	<p>Academic publication retrieval relied on matching inputted keywords to words present in publications; relevant evidence that does not include the keywords is not captured.</p> <p>Institutional websites have several types of search engines for publications, each using different algorithms.</p>	<p>A broad search term, “climate”, was used across key institutional websites to minimize papers not getting captured in results (70-100% of evidence was scraped across each website).</p> <p>Long lists of keywords were used to cast the widest net possible, with manual data checking ensuring no keywords led to false positives.</p>
<b>Data cleaning</b>	<p>Publications with irrelevant topics were included in the longlist of publications due to similarities in the language used for the topic of “climate change x health impact”.</p>	<p>Academic and institutional data were cleaned post-pull with new sets of keywords:</p> <ul style="list-style-type: none"> <li>– Academic cleaning relied on manual filtering out of evidence with the wrong focus (e.g. plants) based on keywords.</li> <li>– Institutional data cleaning relied on filtering by keywords to remove erroneous types of evidence (e.g. newsletters).</li> </ul> <p>Approximately 500 articles were manually checked to define and test the keywords for the cleaning process.</p>
<b>Relevant data quantification</b>	<p>Quantification of evidence relied on keywords chosen for “climate change x health area” intersections; relevant evidence that did not include the keywords would have been filtered out.</p>	<p>L.E.K. maximized the amount of data captured by capturing either the abstract, full webpage or the first 6 pages of the document, reducing the likelihood of missing keywords.</p>
<b>Categorization</b>	<p>Categorization of pieces of text into sentiment-related buckets was a complex computational process. L.E.K.’s solution used keywords chosen for each category and was limited by keyword selection (missing keywords could lead to false negatives); furthermore, a mentioned keyword not used in the context implied would still be categorized (leading to false positives).</p>	<p>The team evaluated the accuracy of using keywords for sentiment analysis against the typical accuracy of general language models used in industry at the initial stages of the project and deemed the keywords acceptable (both at approximately 80% accuracy).</p> <p>Keywords were developed using a tool that identifies the most frequently used words in manually categorized evidence. The categorization is then applied to the full sample and manually tested for validity.</p> <p>A confidence level of “1 keyword per 200 words” was used to reduce false positives in publications with varying lengths. The confidence level achieved approximately 70-80% accuracy in tested evidence.</p>

# A.5 Causal chain analysis of priority topics

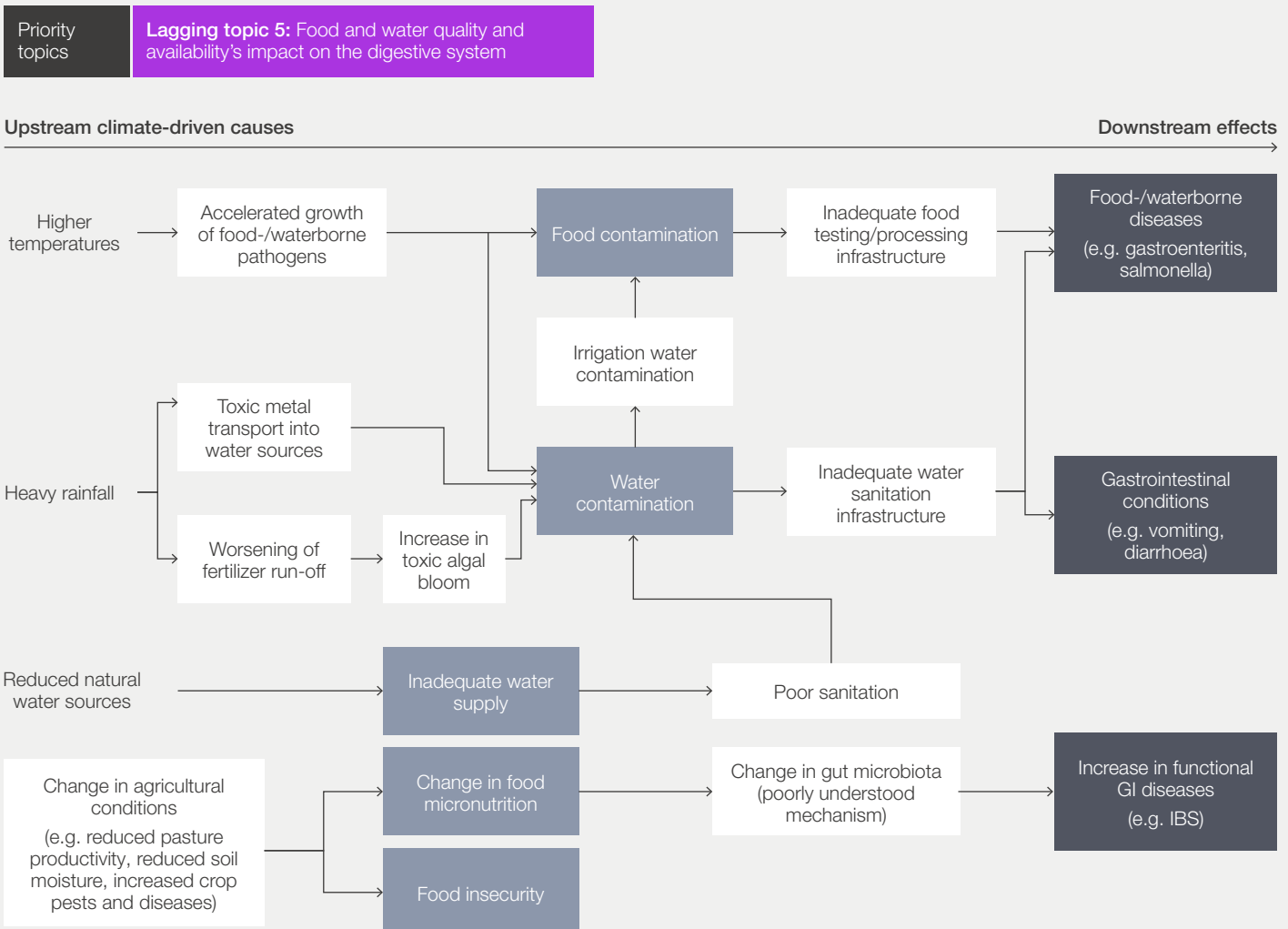
The causal chain linking climate manifestations to their downstream health impact was analysed for the 22 priority topics to identify the drivers involved in perpetuating the relevant health impact of climate change.

FIGURE 16 Causal chain analysis

## Cardiovascular system



## Digestive system

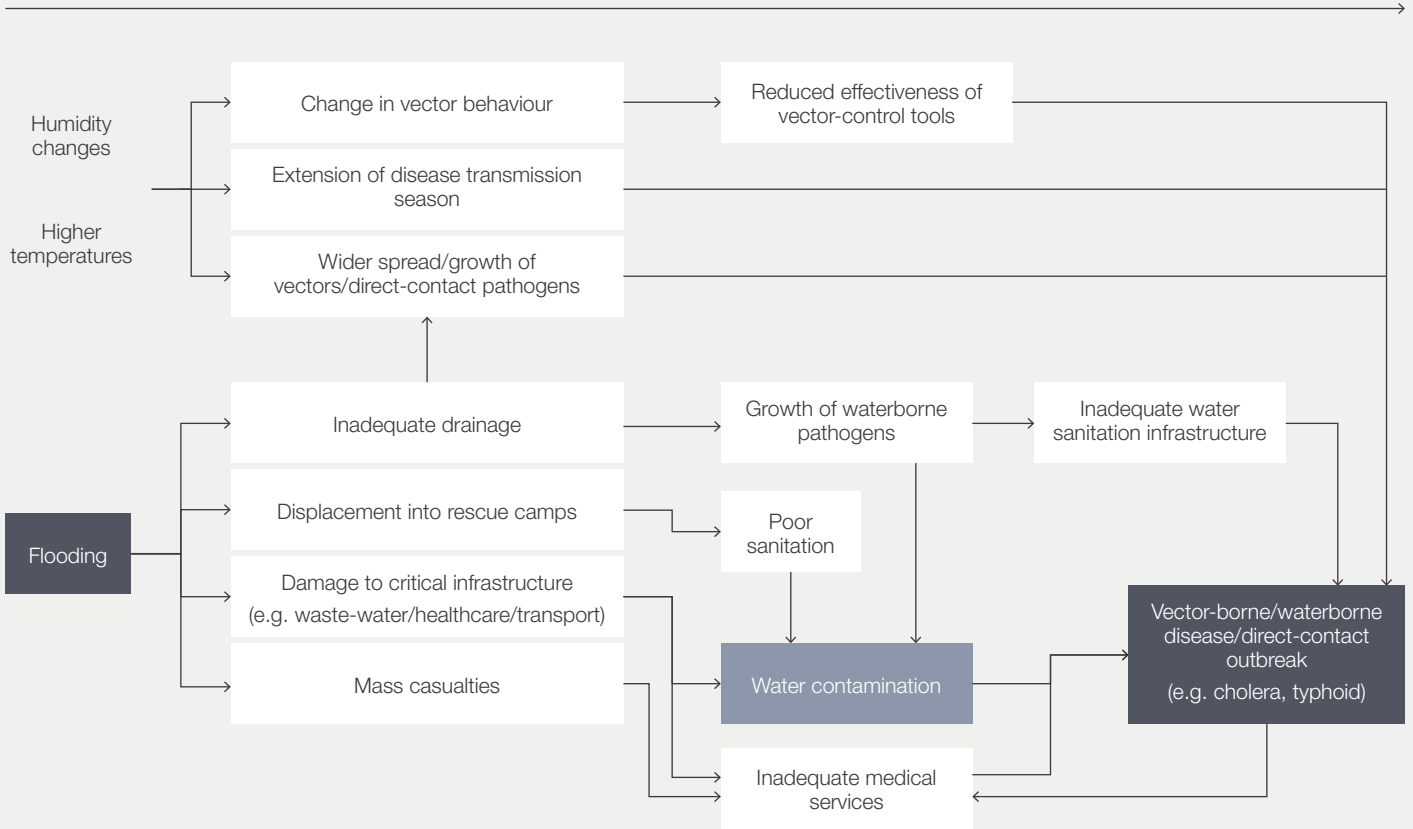


## Immune system and infectious diseases

Priority topics	<b>Hot topic 1:</b> Impact of flooding on infectious diseases	<b>Hot topic 8:</b> Impact of water quality on infectious diseases	<b>Hot topic 8:</b> Impact of vector-borne and direct-contact diseases on the immune system
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Upstream climate-driven causes

Downstream effects

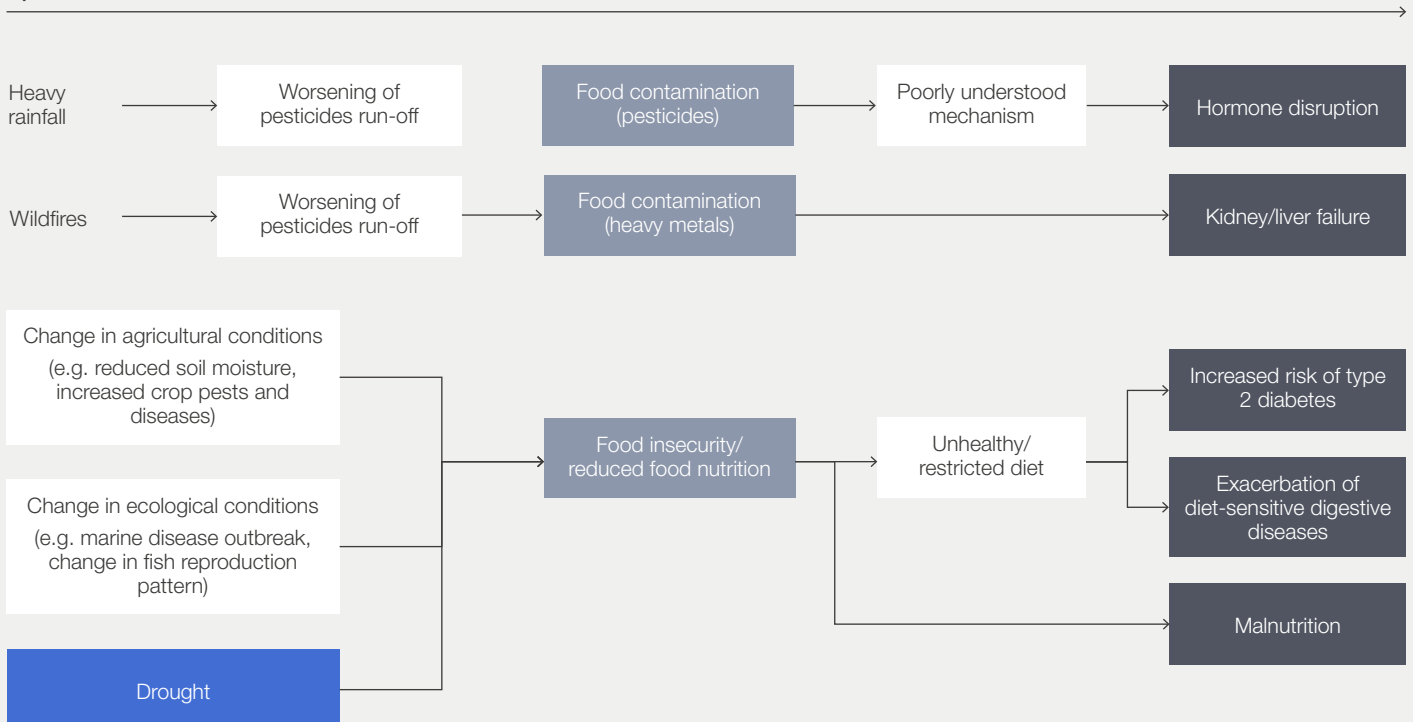


## Nutritional and metabolic diseases

Priority topics	<b>Hot topic 2:</b> Drought's impact on nutritional and metabolic diseases	<b>Hot topic 9:</b> Food quality and availability's impact on nutritional and metabolic diseases
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Upstream climate-driven causes

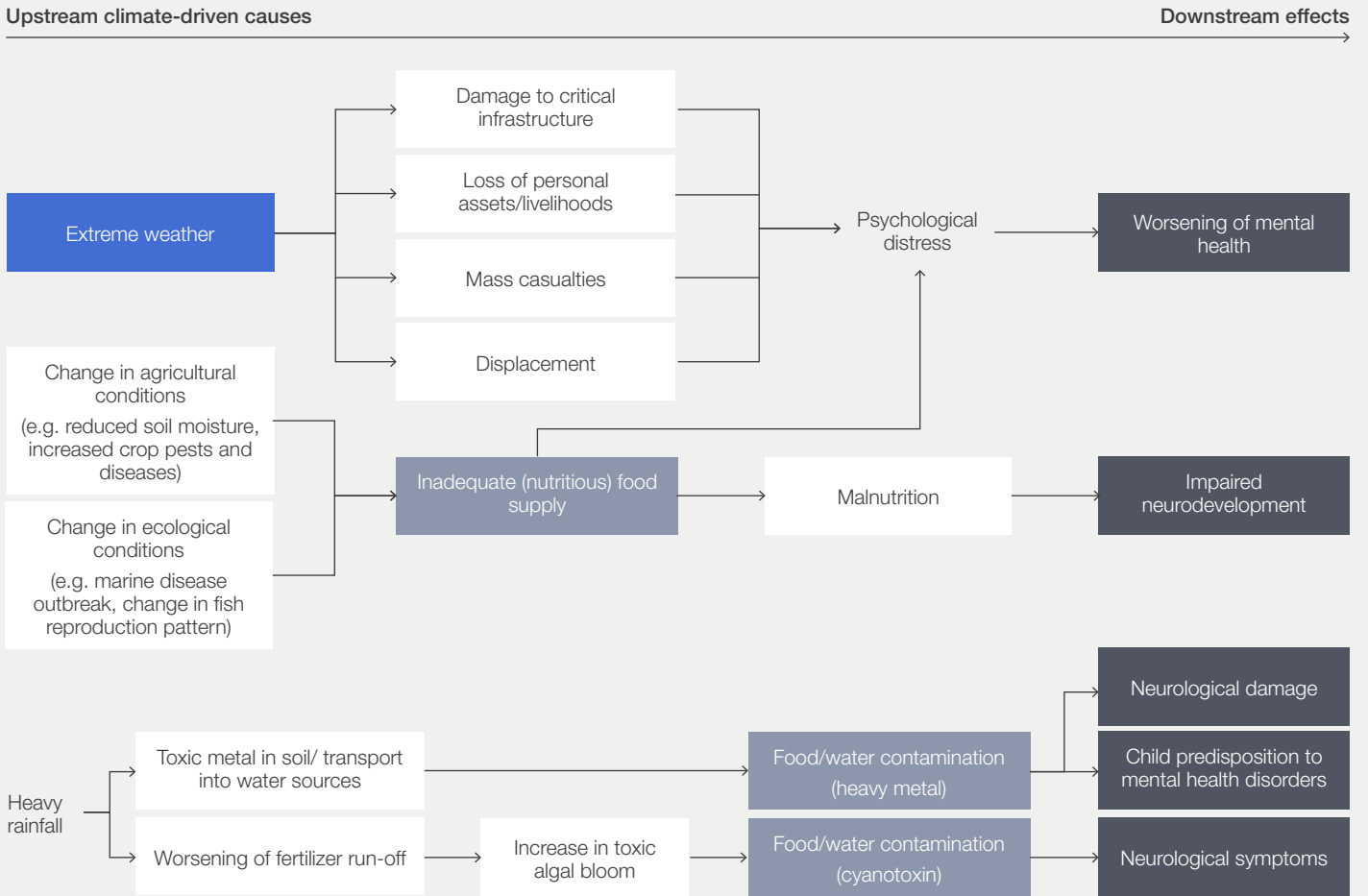
Downstream effects





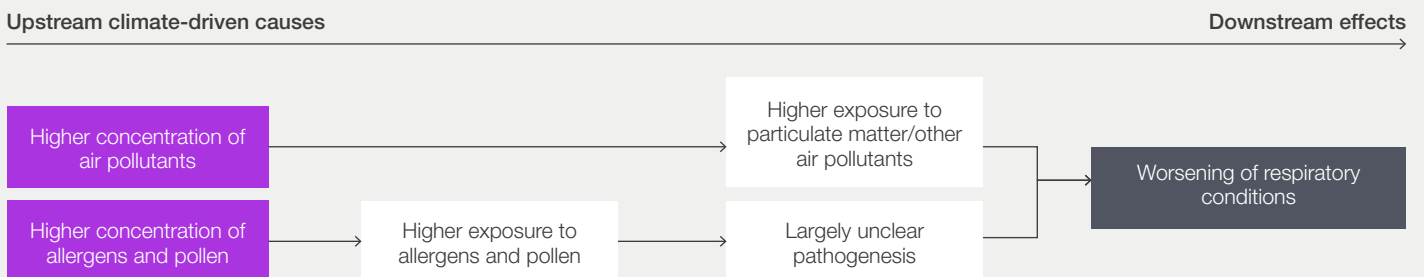
## Neurodevelopment and mental health

Priority topics	Hot topic 4: Drought's impact on nutritional and metabolic diseases	Hot topic 10: Impact of food and water quality and availability on neurodevelopment and mental health
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## Respiratory system

Priority topics	Hot topic 1: Impact of air pollutants on the respiratory system	Lagging topic 4: Allergens and pollen's impact on the respiratory system
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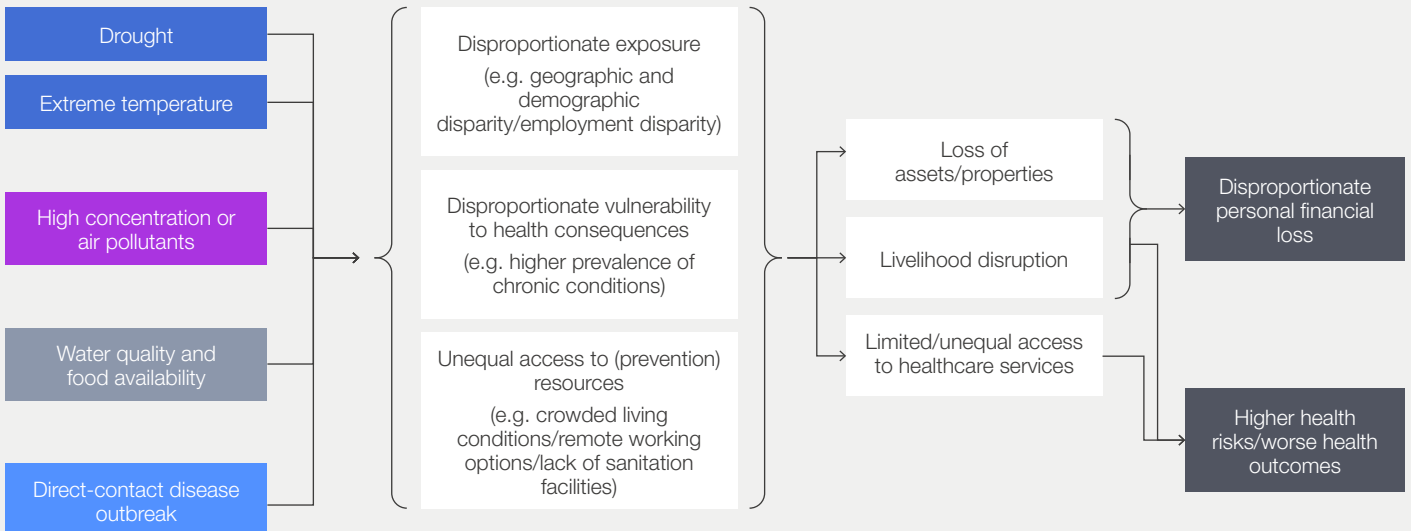


## Social inequality and personal financial loss

Priority topics	<b>Hot topic 5:</b> Impact of drought and extreme temperature on social inequality and personal financial loss	<b>Hot topic 7:</b> Impact of air pollutants on social inequality	<b>Hot topic 11:</b> Impact of water quality and food availability on social inequality	<b>Hot topic 13:</b> Impact of direct contact diseases on social inequality and personal financial loss
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### Upstream climate-driven causes

### Downstream effects



## Displacement and migration

Priority topics	<b>Lagging topic 1:</b> Impact of extreme weather events on displacement and migration	<b>Lagging topic 8:</b> Impact of water and food availability on involuntary migration
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### Upstream climate-driven causes

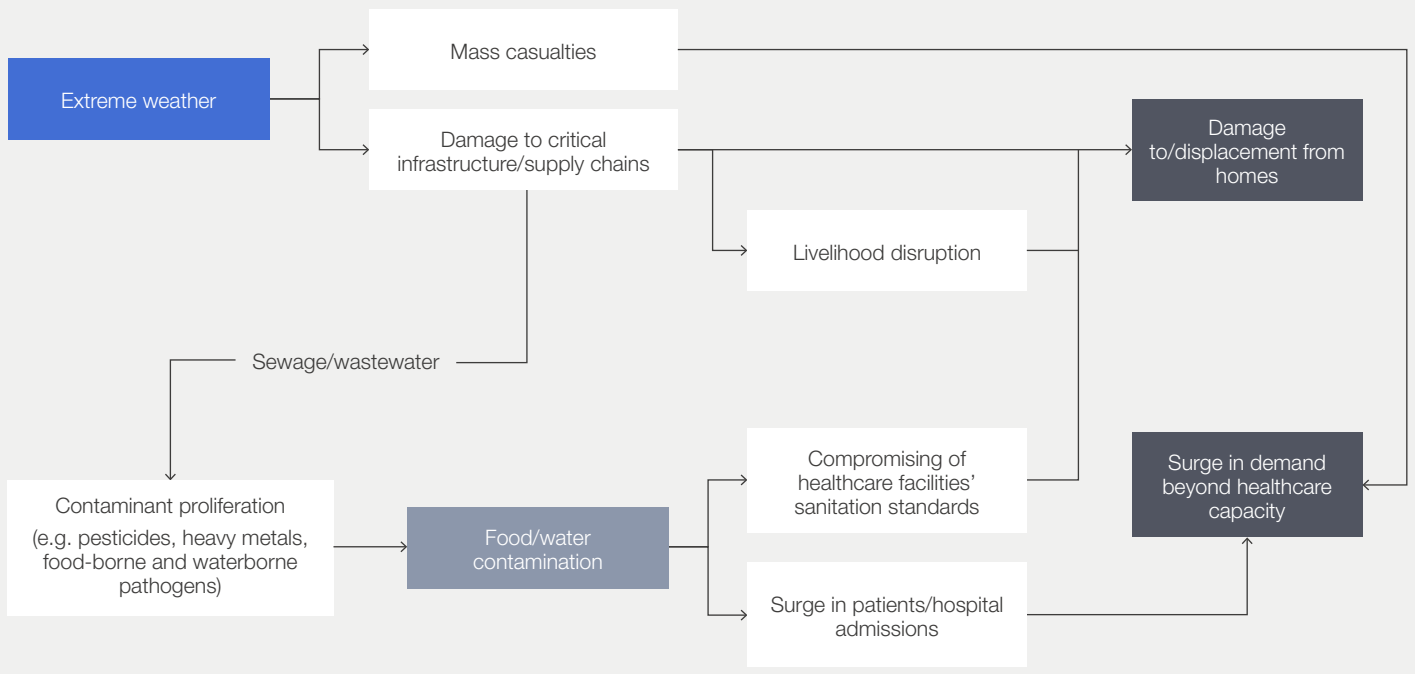
### Downstream effects



# Health systems and infrastructure disruption

Priority topics	<b>Lagging topic 6:</b> Impact of extreme weather on healthcare system and infrastructure disruption	<b>Lagging topic 8:</b> Impact of food and water quality and security on healthcare system and infrastructure disruption	<b>Lagging topic 9:</b> Impact of infectious diseases on healthcare system and infrastructure disruption
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Upstream climate-driven causes Downstream effects



### Climate change themes

- Extreme weather
- Air quality
- Food and water
- Infectious agents
- Contributing factors
- Priority health areas affected

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# Endnotes

1. World Economic Forum. (2024). Global Risks Report 2024. Geneva.
2. Ibid.
3. Development Initiatives. (2023). Climate vulnerability, climate finance (ODA) and protracted crisis.
4. World Bank. (2023). COP28 – Adapting to Climate Change in Fragile and Conflict Settings: Opportunities for Scaling Action. Retrieved from <https://live.worldbank.org/en/event/2023/cop28-adapting-to-climate-change-in-fcv-settings-opportunities-for-scaling-action#:~:text=But%201%20will%20be%20very,the%20World%20Bank%20is%20tracking>.
5. Centre of Excellence Climate and Disaster Resilience. (2023). Policy Paper: Early Warning Systems and Early Action in Fragile, Conflict and Violent Contexts: Addressing growing climate and disaster risks.
6. The Loss and Damage Collaboration. (2022). The Cost of Delay: Why Finance to Address Loss and Damage Must Be Agreed At COP27. Retrieved from <https://www.oxfam.org/en/press-releases/189-million-people-year-affected-extreme-weather-developing-countries-rich-countries>.
7. World Health Organization. (n.d.). 10 Things To Know About Air Pollution.
8. United Nations. (2022). The State of Food Security and Nutrition in the World (SOFI).
9. U.S. Department of Agriculture. (2019). Who Are the World's Food Insecure? Identifying the Risk Factors of Food Insecurity Around the World. Retrieved from <https://www.ers.usda.gov/amber-waves/2019/june/who-are-the-world-s-food-insecure-identifying-the-risk-factors-of-food-insecurity-around-the-world/>.
10. World Health Organization. (2019). Progress on drinking water, sanitation and hygiene: 2000-2017: Special focus on inequalities.
11. Authia Gray, F.S. (2022). Global and regional sepsis and infectious syndrome mortality in 2019: a systematic analysis. *The Lancet Global Health*, 10.
12. Camilo Mora, T.M. (2022). Over half of known human pathogenic diseases can be aggravated by climate change. *Nature Climate Change*, 869-875.
13. Full details of the scraping methodology, limitations and mitigation methods are included in section A4 of the appendix, inclusion the criteria, keywords used, the data cleaning exclusion filters, as well as the limitations of scraping and mitigation strategies.
14. Defined as having a large number of high-impact intersections.
15. World Health Organization. (2023). Climate change. Retrieved from <https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health#:~:text=Temperature%20and%20precipitation%20changes%20enhance,700%20000%20annually%2C%20may%20rise>; World Meteorological Organization. (n.d.). ClimaHealth Hazards. Retrieved from <https://climahealth.info/hazards/>; National Institute of Environmental Health Sciences. (n.d.). Human Health Impacts of Climate Change. Retrieved from [https://www.niehs.nih.gov/research/programs/climatechange/health\\_impacts](https://www.niehs.nih.gov/research/programs/climatechange/health_impacts); Planetary Health Alliance. (n.d.). Environmental changes and health impacts: Thematic areas . Retrieved from <https://www.planetaryhealthalliance.org/planetary-health>; Wellcome Trust. (2022). The health effects of climate change, explained. Retrieved from <https://wellcome.org/news/how-climate-change-affects-health-explained>.
16. United Nations Environment Programme. (n.d.). Extreme weather. Retrieved from <https://leap.unep.org/en/knowledge/glossary/extreme-weather>.
17. World Meteorological Organization. (2024). Extreme weather. Retrieved from <https://wmo.int/topics/extreme-weather#:~:text=Extreme%20heatwaves%20in%202003%20and,in%20Europe%20from%201970%2D2019.&text=Extreme%20temperatures%20of%2040%2B%C2%B0,are%20becoming%20increasingly%20frequent%20worldwide.&text=Limiting%20global%20warming%20>.
18. UN Office of Disaster Risk Reduction, Centre for Research on the Epidemiology of Disasters. (2022). Human cost of disasters. An overview of the last 20 years (2000-2019).
19. World Meteorological Organization. (2022). WMO Provisional State of the Global Climate. Retrieved from [https://library.wmo.int/viewer/56335?medianame=Provisional State of the Climate 2022\\_en\\_#page=18&viewer=picture&o=bookmark&n=0&q=](https://library.wmo.int/viewer/56335?medianame=Provisional%20State%20of%20the%20Climate%202022_en_#page=18&viewer=picture&o=bookmark&n=0&q=).
20. Sendai Framework Monitor. (2023). Snapshot of Sendai Framework Monitoring. Retrieved from <https://sendaimonitor.undrr.org/>.
21. World Bank. (2023). Adapting to Climate Change in Fragile and Conflict Settings: Opportunities for Scaling Action; Centre of Excellence Climate and Disaster Resilience. (2023). Policy Paper: Early Warning Systems and Early Action in Fragile, Conflict and Violent Contexts: Addressing growing climate and disaster risks; World Meteorological Organization. (2023). Early Warning Systems must address risks in fragile and conflict-affected contexts. Retrieved from <https://wmo.int/media/news/early-warning-systems-must-address-risks-fragile-and-conflict-affected-contexts>.
22. Lopez, A.M., Pacheco, J.L., and Fendorf, S. (2023). Metal toxin threat in wildland fires determined by geology and fire severity. *Nature Communications*, 14(1).
23. World Meteorological Organization. (2022). WMO Air Quality and Climate Bulletin No. 2 - September 2022.

24. Climate and Clean Air Coalition. (n.d.). Short-lived Climate Pollutants.
25. Centers for Disease Control and Prevention. (2023). Particle Matter (PM) Basics. Retrieved from <https://www.epa.gov/pm-pollution/particulate-matter-pm-basics>.
26. American Lung Association. (2023). Particle Pollution. Retrieved from <https://www.lung.org/clean-air/outdoors/what-makes-air-unhealthy/particle-pollution#sources>.
27. Climate ADAPT. (n.d.). Pollen. Retrieved from <https://climate-adapt.eea.europa.eu/en/observatory/evidence/health-effects/aeroallergens/pollen>.
28. The European Union. (n.d.). Forecasting pollen to alleviate allergy suffering. Retrieved from <https://stories.ecmwf.int/forecasting-pollen-to-alleviate-allergy-suffering/index.html>.
29. European Environment Agency. (2022). Air Pollution and health. Retrieved from <https://www.eea.europa.eu/publications/zero-pollution/health/air-pollution#:~:text=In%202020%2C%20the%20vast%20majority,value%20of%205%C2%B5g%2Fm3>.
30. Ibid.
31. United Nations. (n.d.). Water - at the centre of the climate crisis. Retrieved from <https://www.un.org/en/climatechange/science/climate-issues/water>; U.S. Environmental Protection Agency. (2023). Climate Change Impacts on Agriculture and Food Supply. Retrieved from <https://www.epa.gov/climateimpacts/climate-change-impacts-agriculture-and-food-supply>.
32. Food and Agriculture Organization. (2015). Climate change and food security: risks and responses; Jessica C. Fanzo, S. M. (2021). Climate change and nutrition-associated diseases. Nature reviews disease primers.
33. United Nations. (2022). The Sustainable Development Goals Report 2022 – Goal 6.
34. UNICEF. (2023). Triple Threat. How disease, climate risks and unsafe water, sanitation and hygiene create a deadly combination for children.
35. Food and Agriculture Organization of the United Nations. (2021). Prevalence of moderate or severe food insecurity in the population (%). Retrieved from <https://data.worldbank.org/indicator/SN.ITK.MSFI.ZS>.
36. Wellcome Trust. (2023). How climate change affects vector-borne diseases . Retrieved from <https://wellcome.org/news/how-climate-change-affects-vector-borne-diseases>.
37. World Health Organization. (2023). Climate change. Retrieved from <https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health#:~:text=Temperature%20and%20precipitation%20changes%20enhance,700%20000%20annually%2C%20may%20rise>.
38. Sadie J. Ryan, C.J. (2019). Global expansion and redistribution of Aedes-borne virus transmission risk with climate change. PLOS Neglected Tropical Diseases.
39. Ryan S.J. (2021). Warming temperatures could expose more than 1.3 billion new people to Zika virus risk by 2050. Global Change Biology, 84-93.
40. World Bank Blogs. (2020). Fighting infectious diseases: The connection to climate change. Retrieved from <https://blogs.worldbank.org/en/climatechange/fighting-infectious-diseases-connection-climate-change>; Harvard School of Public Health. (n.d.). Nutrition and Immunity. Retrieved from <https://www.hsph.harvard.edu/nutritionsource/nutrition-and-immunity/>.
41. World Health Organization. (2023). World Malaria Report.
42. Camilo Mora (2022). Over half of known human pathogenic diseases can be aggravated by climate change. Nature Climate Change, 869-875.
43. Xiao Wu (2020). Exposure to air pollution and COVID-19 mortality in the United States: A nationwide cross-sectional study. medRxiv.
44. Wellcome Trust. (2023). How climate change affects vector-borne diseases . Retrieved from <https://wellcome.org/news/how-climate-change-affects-vector-borne-diseases>.
45. U.S. Global Change Research Program. (2016). The Impacts of Climate Change on Human Health in the United States. Retrieved from [https://health\\_016.globalchange.gov/low/ClimateHealth\\_016\\_FullReport\\_small.pdf](https://health_016.globalchange.gov/low/ClimateHealth_016_FullReport_small.pdf).
46. World Bank. (2023). The Development, Climate and Nature Crisis.
47. International Classification of Diseases (11th revision) (WHO, 2023).
48. The full definition of indirect health determinants is noted in section A2 in the appendix.
49. Approximately 350 documents were reviewed to complete the impact scoring analysis, covering literature and documents by leading organizations in the climate and health space, including from the academia, government and public health agencies, non-government organizations (NGOs) and other stakeholder types.
50. Full details of the scraping methodology, limitations and mitigation methods are included in section A4 of the appendix, inclusion the criteria, keywords used, the data cleaning exclusion filters, as well as the limitations of scraping and mitigation strategies.
51. Germanwatch. (2021). Global Climate Risk Index 2021.
52. Percentile ranking based on the Climate Risk Index (CRI) Score reported in Germanwatch. (2021). Global Climate Risk Index 2021.
53. International Society of Quality of Life. (n.d.). What is quality of life? Retrieved from <https://www.isoqol.org/what-is-qol/>.

54. UN Women. (2022). How gender inequality and climate change are interconnected. Retrieved from <https://www.unwomen.org/en/news-stories/explainer/2022/02/explainer-how-gender-inequality-and-climate-change-are-interconnected#:~:text=The%20climate%20crisis%20is%20not,less%20access%20to%2C%20natural%20resources.>
55. Centre for Climate Engagement. (n.d.). Criminal law and climate change. Retrieved from [https://climatehughes.org/law-and-climate-atlas/criminal-law-and-climate-change/#\\_ftn1](https://climatehughes.org/law-and-climate-atlas/criminal-law-and-climate-change/#_ftn1).
56. Harvard Health. (n.d.). Heart problems and the heat: What to know and do. Retrieved from <https://www.health.harvard.edu/blog/heart-problems-and-the-heat-what-to-know-and-do-202206212765>; US Environmental Protection Agency. (2023). Climate Change Impacts on Agriculture and Food Supply. Retrieved from <https://www.epa.gov/climateimpacts/climate-change-impacts-agriculture-and-food-supply>.
57. Y. Li (2018). Heat wave and health risk early warning systems in China. WHO/WMO Climate Services for Health: Improving public health decision-making in a new climate.
58. J. Guo et al. (2022). Allergic asthma is a risk factor for human cardiovascular diseases. *Nature Cardiovascular Research*, 1(5), 417-430; J.J.K. Jaakkola et al. (2021). Airborne pollen concentrations and daily mortality from respiratory and cardiovascular causes. *European Journal of Public Health*, 31(4), 722-724.
59. Centers for Disease Control and Prevention, 2020.
60. World Health Organization. (2024). Sanitation. Retrieved from <https://www.who.int/news-room/fact-sheets/detail/sanitation>.
61. Anahita Sadeghi et al. (2023). Mini Review: The Impact of Climate Change on Gastrointestinal Health. *Middle East Journal of Digestive Diseases*, 15(2), 72-75.
62. United Nations. (n.d.). Water – at the centre of the climate crisis. Retrieved from <https://www.un.org/en/climatechange/science/climate-issues/water>; Centers for Disease Control and Prevention. (2022). Water contamination and diseases. Retrieved from <https://www.cdc.gov/healthywater/drinking/contamination.html>.
63. G.E.C. Charnley et al. (2021). Traits and risk factors of post-disaster infectious disease outbreaks: a systematic review. *Scientific Reports*.
64. World Health Organization. (2023). World Malaria Report.
65. Centers for Disease Control and Prevention. (2023). Particle Pollution. Retrieved from [https://www.cdc.gov/air/particulate\\_matter.html](https://www.cdc.gov/air/particulate_matter.html).
66. UNICEF. (2022). At least 10 million children face severe drought in the Horn of Africa. Retrieved from <https://www.unicef.org/press-releases/least-10-million-children-face-severe-drought-horn-africa-unicef>.
67. Global Health Advocates. (2018). Ending malnutrition: what role for the private sector?
68. Hilary K. Seligman et al. (2010). Food Insecurity Is Associated with Chronic Disease among Low-Income NHANES Participants. *Journal of Nutrition*.
69. Global Health Advocates. (2018). Ending malnutrition: what role for the private sector?
70. Food and Agriculture Organization. (n.d.). Agricultural sub-sectors - decent rural employment. Retrieved from <https://www.fao.org/rural-employment/agricultural-sub-sectors/ru>.
71. T.E. Stoker et al. (2010). Pesticides as endocrine-disrupting chemicals. In Hayes Handbook of Pesticide Toxicology (new edition) (pp. 551-569).
72. Pesticide Action Network. (2022). Pesticides & Climate Change: A Vicious Cycle. Retrieved from <https://www.panna.org/news/pesticides-climate-change-a-vicious-cycle#:~:text=Increased%20temperatures%20are%20expected%20to,pesticide%20loss%20to%20our%20waterways.>
73. American Psychiatric Association. (2021). Extreme Heat Contributes to Worsening Mental Health, Especially Among Vulnerable Populations. Retrieved from <https://www.psychiatry.org/news-room/news-releases/extreme-heat-contributes-to-worsening-mental-health#:~:text=Extreme%20heat%20has%20been%20associated.with%20an%20increase%20in%20suicide>; Wellcome Trust. (2022). The health effects of climate change, explained. Retrieved from <https://wellcome.org/news/how-climate-change-affects-health-explained>; Jesse D. Berman et al. (2021). The association between drought conditions and increased occupational psychosocial stress among U.S. farmers: An occupational cohort study. *Science of The Total Environment*; Substance Abuse and Mental Health Services Administration. (2023). Wildfires. Retrieved from <https://www.samhsa.gov/find-help/disaster-distress-helpline/disaster-types/wildfires>.
74. Inter-Agency Standing Committee. (2007). Guidelines on Mental Health and Psychosocial Support in Emergency Settings.
75. American Psychological Association. (2020). Resilience in the age of devastating storms. Retrieved from <https://www.apa.org/monitor/2020/11/feature-resilience-storms>.
76. Emma L. Lawrance et al. (2022). The Impact of Climate Change on Mental Health and Emotional Wellbeing: A Narrative Review of Current Evidence and its Implications. *International Review of Psychiatry*; Proof Food insecurity policy research. (2022). What are the implications of food insecurity for health and health care? Retrieved from <https://proof.utoronto.ca/food-insecurity/what-are-the-implications-of-food-insecurity-for-health-and-health-care/>.
77. Ann Aschengrau et al. (2016). Long-Term Neurotoxic Effects of Early Life Exposure to Tetrachloroethylene-contaminated Drinking Water. *Annals of Global Health*, 82(1), 169-179.
78. U.S. Global Change Research Program. (2016). Food Safety, Nutrition, and Distribution.
79. Ansuya, B.S. (2023). Effect of nutrition intervention on cognitive development among malnourished preschool children: randomized controlled trial. *Scientific Reports*, p. 10636.

80. Emilia Basilio et al. (2022). Wildfire Smoke Exposure during Pregnancy: A Review of Potential Mechanisms of Placental Toxicity, Impact on Obstetric Outcomes and Strategies to Reduce Exposure. *International Journal of Environmental Research and Public Health*; Centers for Disease Control and Prevention. (2022). Water contamination and diseases. Retrieved from <https://www.cdc.gov/healthywater/drinking/contamination.html>; Hossein Amarpoor Mesrkanlou et al. (2022). The Effect of an Earthquake Experienced During Pregnancy on Maternal Health and Birth Outcomes. Cambridge University Press; United Nations Population Fund. (2018). *Earthquake and tsunami devastating for 45,000 pregnant women in Indonesia*. Retrieved from <https://www.unfpa.org/news/earthquake-and-tsunami-devastating-45000-pregnant-women-indonesia>.
81. Yale Scientific. (2010). Influenza Renders Immune System Vulnerable. Retrieved from <https://www.yalescientific.org/2010/10/influenza-renders-immune-system-vulnerable/#:~:text=Medzhitov%20is%20the%20first%20to%20establishes%20itself%20in%20the%20lungs>; Centers for Disease Control and Prevention. (2018). Intermittent Preventive Treatment of Malaria for Pregnant Women (IPTp). Retrieved from [https://www.cdc.gov/malaria/malaria\\_worldwide/reduction/iptp.html#:~:text=Malaria%20infection%20during%20pregnancy%20can,a%20risk%20factor%20for%20death](https://www.cdc.gov/malaria/malaria_worldwide/reduction/iptp.html#:~:text=Malaria%20infection%20during%20pregnancy%20can,a%20risk%20factor%20for%20death); Centers for Disease Control and Prevention. (2019). Pregnancy. Retrieved from <https://www.cdc.gov/zika/pregnancy/index.html>.
82. UNICEF. (2023). Antenatal care is essential for protecting the health of women and their unborn children. Retrieved from <https://data.unicef.org/topic/maternal-health/antenatal-care/>.
83. Kriebel-Gasparro, A. (2022). Climate Change: Effects on the Older Adult. *The Journal for Nurse Practitioners*, 372-376.
84. European Union. (n.d.). Forecasting pollen to alleviate allergy suffering. Retrieved from <https://stories.ecmwf.int/forecasting-pollen-to-alleviate-allergy-suffering/index.html>; World Health Organization. (2023). *Monitoring air pollution levels is key to adopting and implementing WHO's Global Air Quality Guidelines*. Retrieved from <https://www.who.int/news/item/10-10-2023-monitoring-air-pollution-levels-is-key-to-adopting-and-implementing-who-s-global-air-quality-guidelines>.
85. United Nations Convention to Combat Desertification. (2022). DROUGHT IN NUMBERS 2022.
86. Jun Rentschler et al. (2023). Global air pollution exposure and poverty. *Nature communications*.
87. Abimbola Ayorinde et al. (2023). Health inequalities in infectious diseases: a systematic overview of reviews. *BMJ Open*.
88. Internal displacement monitoring centre. (2022). DISASTER DISPLACEMENT IN ASIA AND THE PACIFIC; Internal displacement monitoring centre. (2019). DISPLACEMENT AND HOUSING AFFORDABILITY IN THE UNITED STATES. (Utah State University ) Retrieved from <https://www.internal-displacement.org/expert-analysis/displacement-and-housing-affordability-in-the-united-states/>; Climate and Migration Coalition. (n.d.). Six things governments should do about hurricane displacement right now. Retrieved from <https://climatemigration.org.uk/six-things-governments-should-do-about-hurricane-displacement-right-now/>; Intergovernmental Panel on Climate Change. (2007). *Climate Change 2007: Working Group II: Impacts, Adaptation and Vulnerability*.
89. Internal displacement monitoring centre. (2023). COP28: WHAT DID IT SAY ABOUT DISPLACEMENT AND CLIMATE CHANGE? Retrieved from <https://www.internal-displacement.org/expert-opinion/cop28-what-did-it-say-about-displacement-and-climate-change>.
90. TRT World. (2022). Five countries most affected by climate displacement. Retrieved from <https://www.trtworld.com/magazine/five-countries-most-affected-by-climate-displacement-50919>.
91. World Bank. (n.d.). Lack of Water Linked to 10 Percent of the Rise in Global Migration. Retrieved from <https://www.worldbank.org/en/news/press-release/2021/08/23/lack-of-water-linked-to-10-percent-of-the-rise-in-global-migration>.
92. TRT World. (2022). Five countries most affected by climate displacement. Retrieved from <https://www.trtworld.com/magazine/five-countries-most-affected-by-climate-displacement-50919>.
93. Lancet Countdown. (2022). The 2022 report of the Lancet Countdown on health and climate change: health at the mercy of fossil fuels.
94. Brooke K. Decker et al. (2014). Hospital water and opportunities for infection prevention. *Current Infectious Disease Reports*; Susan Assanasen, G. M. (2018). FOOD: CONSIDERATIONS FOR HOSPITAL INFECTION CONTROL. Retrieved from <https://isid.org/guide/infectionprevention/hospital-food/>; Center on Budget and Policy Priorities. (2018). Food-Insecure Households Likelier to Have Chronic Diseases, Higher Health Costs. Retrieved from <https://www.cbpp.org/blog/food-insecure-households-likelier-to-have-chronic-diseases-higher-health-costs>.
95. N. A. Yusoff et al. (2017). The impact of floods in hospital and mitigation measures: A literature review; United States Environmental Protection Agency. (n.d.). Research Shows Health Impacts and Economic Costs of Wildland Fires. Retrieved from <https://www.epa.gov/sciencematters/research-shows-health-impacts-and-economic-costs-wildland-fires>; Vikas Kumar, et al. (2018). Malaria and dengue: Knowledge, attitude, practice and effect of sensitization workshop among schoolteachers as health educators. *Journal of Family Medicine and Primary Care*; International Monetary Fund. (2018). Epidemics and Economics. Retrieved from <https://www.imf.org/en/Publications/fandd/issues/2018/06/economic-risks-and-impacts-of-epidemics-bloom#:~:text=A%20sizable%20outbreak%20can%20overwhelm,driving%20down%20and%20disrupting%20productivity>.
96. Samantha L. Waddell, et al. (2021). Perspectives on the Health Effects of Hurricanes: A Review and Challenges. *International Journal of Environmental Research and Public Health*.
97. Climate Policy Initiative. (2022). Global Landscape of Climate Finance: A Decade of Data.
98. United States Environmental Protection Agency. (2023). Causes of Climate Change. Retrieved from <https://www.epa.gov/climatechange-science/causes-climatechange#:~:text=Since%20the%20Industrial%20Revolution%2C%20human,also%20affect%20the%20earth's%20climate>; UNICEF. (2023). The climate-changed child.



99. United States Environmental Protection Agency. (2023). Climate Change and the Health of Pregnant, Breastfeeding and Postpartum Women.
100. The State of Global Air. (2020). The State of Global Air Report.
101. UN Women. (2022). How gender inequality and climate change are interconnected. Retrieved from <https://www.unwomen.org/en/news-stories/explainer/2022/02/explainer-how-gender-inequality-and-climate-change-are-interconnected>.
102. London School of Economics. (2013). Understanding the adaptation deficit: why are poor countries more vulnerable to climate events than rich countries?
103. United Nations. (n.d.). On the Frontline of Climate Crisis, Worlds Most Vulnerable Nations Suffer Disproportionately. Retrieved from <https://www.un.org/ohrls/news/frontline-climate-crisis-worlds-most-vulnerable-nations-suffer-disproportionately>.
104. United States Environmental Protection Agency. (2023). Climate Change and the Health of Socially Vulnerable People. Retrieved from <https://www.epa.gov/climateimpacts/climate-change-and-health-socially-vulnerable-people>.
105. Association of American Medical Colleges. (2023). Rural Americans find little escape from climate change. Retrieved from <https://www.aamc.org/news/rural-americans-find-little-escape-climate-change>.
106. Climate Policy Initiative. (2022). Global Landscape of Climate Finance: A Decade of Data.
107. World Meteorological Organization. (1970-2019). The Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes.
108. United Nations Office for Disaster Risk Reduction, World Meteorological Organization. (2023). Global status of multi-hazard early warning systems 2023.
109. Ibid.
110. Access to Medicine Foundation. (2022). Access to Medicine Index.
111. Louise C. Druedahl, T. M. (2021). Collaboration in times of crisis: A study on COVID-19 vaccine R&D partnerships. Vaccine.
112. World Health Organization. (2021). The role of the private health sector in COVID-19 response.
113. World Health Organization. (2023). Climate Change. Retrieved from <https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health>; World Bank, World Health Organization. (2023). Tracking Universal Health Coverage: 2023 Global Monitoring Report.
114. World Health Organization. (2020). COVID-19 disrupting mental health services in most countries.
115. UNICEF. (2021). The State of the World's Children.
116. World Bank. (2021). Frontline: Preparing Healthcare Systems for Shocks from Disasters to Pandemics.
117. Rimmer, A. (2020). Covid-19: Private hospitals commit to training juniors who help to tackle backlog. British Medical Journal, 370:m3517.
118. Sameen Siddiqi, et al. (2023). The role of the private sector in delivering essential packages of health services: lessons from country experiences. BMJ Global Health, 8 (supplement 1).
119. PayNearby. (2023).
120. European Centre for Disease Prevention and Control. (2021). Risk of infectious diseases in flood-affected areas from the European Union. Retrieved from <https://www.ecdc.europa.eu/en/news-events/risk-infectious-diseases-flood-affected-areas-european-union>.
121. Access to Medicine Foundation. (2022). Access to Medicine Index.
122. United Nations Office for the Coordination of Humanitarian Affairs, United Nations Office for Disaster Risk Reduction. (2000-2022). Overview of Disasters in Latin America and the Caribbean.
123. Sotirios A. Argyroudis, S. A. (2022). Digital technologies can enhance climate resilience of critical infrastructure. Climate Risk Management.
124. Organisation for Economic Co-operation and Development (OECD). (2018). OECD Environment Policy Paper No.14.
125. US Climate Resilience Toolkit. (n.d.). Retrieved from <https://toolkit.climate.gov/case-studies>.
126. World Bank. (2022). Employment in agriculture.
127. World Economic Forum. (2022). Why smallholder farmers are central to new food security interventions. Retrieved from <https://www.weforum.org/agenda/2022/09/smallholder-farmers-key-achieving-food-security/>.
128. Food and Agriculture Organization of the United Nations. (n.d.). Public-private partnerships boost capacity and know-how in agriculture. Retrieved from <https://www.fao.org/in-action/public-private-partnerships-boost-capacity-in-agriculture/en/>.
129. European Insurance and Occupational Pensions Authority. (2023). The role of insurers in tackling climate change: challenges and opportunities.
130. Access to Insurance Initiative, African Insurance Organisation, the International Association of Insurance Supervisors, the Microinsurance Network. (2017). 10th consultative forum on scaling up agricultural index insurance in Africa: building disaster resilience of smallholder farmer.



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