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Health under climate pressure: An emerging research agenda

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2.1 Introduction

As the health effects of climate change increase, the shortfalls of narrow biomedical understandings of health are becoming even more evident (e.g. IPCC 2023; WHO 2021b; Costello et al. 2009; Millennium Ecosystem Assessment 2005; Lock & Nguyen 2018). An emerging research agenda is crystallising around the connections between climate and health (Romanello et al. 2023; Whitmee et al. 2015; Horton & Lo 2015). This agenda gained momentum with the launch of the Lancet Countdown on Health and Climate Change in 2015, initiated in the wake of the quantitative risk assessment of climate change effects on selected causes of death by the World Health Organization (WHO 2014). By 2023, this initiative represented the most comprehensive research effort to date that 'independently monitors the evolving impacts of climate change on health, and the emerging health opportunities of climate action' (Romanello et al. 2023, p. 1).

One major challenge in understanding these impacts stems from the complex, often indirect and dynamic interactions between climate and health. In this context, Butler (2014, 2018) distinguishes between primary, secondary, and tertiary health effects of climate change: primary effects occur when extreme weather events, such as heatwaves and floods, directly cause deaths, injuries, and diseases;[1] secondary effects arise from changing ecosystem conditions including infectious diseases, vector-borne diseases, food- and water-borne infections, and air quality issues such as allergic reactions (Butler 2018, 2014); and tertiary effects result from contextual dynamics where 'health consequences are modified by numerous cultural, political, economic, social and other effects such as poverty, inequality, population growth, resource scarcity and governance' (Butler 2014, p. 2). Butler and colleagues (Butler et al. 2005; Butler 2014; Smith et al. 2014; Whitmee et al. 2015) argue that tertiary health impacts of climate change require the most urgent attention. They caution that by mid-century, these impacts could surpass the combined effects of primary and secondary health impacts. Despite growing concern across various disciplines, tertiary impacts remain underexplored in the fields of biomedicine, healthcare, and climate sciences.

In this chapter, we ask: How can the health effects of climate change be understood in a way that does justice to the diverse natural, ecosystemic, and societal dynamics[2] shaping these effects? Here—drawing on previous work (Radhuber et al. 2023; Radhuber et al. 2024; Radhuber et al. 2025)—we explore the health impacts of climate change using the example of extreme weather events. Given the lack of research on tertiary health impacts, we pay particular attention to how social, political, and economic dynamics shape the impact that climate change has on health. We propose a multidimensional understanding of health amidst climate change and discuss how complex problems can be analysed through a mixed methods approach that incorporates both qualitative research and transdisciplinary perspectives.

As climate change increases the risk of extreme weather events,[3] ever more people experience the health impacts of heatwaves,[4] heavy rainfall, floods, droughts, storms, and compound events (IPCC 2023; WMO 2022; Seneviratne et al. 2021). Heatwaves and floods are the two most common climate change-induced extreme weather events, both of which can increase health impacts of climate change, such as the transmission of communicable diseases (by microbes, vectors, and reservoir animals), as well as non-communicable diseases, and vulnerability due to displacement, loss of work, or ruptures to the social fabric. According to Talukder et al. (2021), diseases associated with flooding include food- and water-borne infections, conjunctivitis, schistosomiasis, skin and soft tissue infections, and dermatitis. These health issues are further aggravated by contamination of freshwater sources, inadequate sanitation, disrupted healthcare access, infrastructure breakdown, and related challenges (i.e., the tertiary health impacts of climate change). In contrast, droughts can trigger infectious diseases through groundwater contamination by viruses, protozoa, and bacteria, along with pests and diseases introduced by mulching processes. Droughts also raise critical concerns about food insecurity, contamination of agricultural products, and much more. Moreover, these events contribute to non-communicable diseases such as cardiovascular diseases, cancers, respiratory problems, and neurological disorders, due to exposure to algal and fungal biotoxins in contaminated water and food, as well as increased mental health and occupational safety concerns.

Floods (see Table 2.1 for recent examples) have received relatively little scholarly attention, which is why they have been selected as the main focus of this chapter. Most examples—cited throughout the chapter in discussions of tertiary health impacts—concentrate on flash floods, which are sudden, intense events that can occur within minutes or hours of heavy rainfall or rapid snowmelt.

2.2 A multidimensional understanding of health amid climate change

Understanding health in relation to climate change draws attention to the ecological processes that influence the well-being of all living species. Here we take inspiration from advocates of the Rights of Nature, who argued for an 'Earth jurisprudence that allows us once more to assume our rightful place as an integral part of the larger

Table 2.1 Recent examples of flooding

Case	Description
Floods in Bangladesh, June 2022	Bangladesh is one of the countries most affected by climate change, facing increasing risks of flash floods (Germanwatch 2021; LSE 2023). In June 2022, the country experienced its worst floods in living memory, with 80% of the northeastern districts submerged, resulting in at least 141 fatalities and millions of others in the region injured, impoverished, or displaced (Human Rights Watch 2023).
Floods in Pakistan, June 2022	From June to August/September 2022, Pakistan experienced the worst floods in its history. More than 1,700 people died, 22 million people lost their homes, land, and jobs, 800,000 cattle and other livestock perished, and 28,999 schools and clinics were damaged (*The Guardian* 2023).
Floods in Western Germany, July 2021	In July 2021, the low-pressure system Bernd caused flooding in Western Germany. Despite warnings from weather experts and the European Flood Warning System, only residents within 50 metres of the river were asked to leave their homes. However, the floods affected people up to 250 metres away, claiming over 180 lives in addition to a €4.5 to 5.5 billion damage (BPB 2022; GDV 2022).
Floods in Southern Austria, August 2023 Update: Floods in Central Europe, September 2024	In early August 2023, heavy flooding affected parts of Southern Styria and Lower Carinthia due to the Zacharias Low. Rainfall reached 200 litres per square metre in five days, with almost 300 litres recorded in Slovenia. Evacuations took place, and at least six people died in Slovenia and Austria (*Die Zeit* 2023; BML 2024). In September 2024, Storm Boris caused severe flooding in Austria, the Czech Republic, Hungary, Poland, Romania, and Slovakia. With up to five times the average September rainfall in just four days, the storm led to widespread evacuations and claimed the lives of at least 21 people, with several still missing.
Floods in East Africa, April 2024	In April 2024, East Africa experienced heavy rainfall and flooding, particularly Kenya, Tanzania, and Burundi. More than 200 people died, 100,000 were displaced, and damage to farmland and infrastructure was reported (*The Guardian* 2024). As of 30 May 2024, reports even indicated that 528 people had lost their lives, over 480,000 people had been displaced, and 1.6 million were affected by the flooding event, primarily in Kenya, Ethiopia, and Somalia (UNOCHA 2024).
Floods in Brazil, February 2022	On 15 February 2022, the city of Petrópolis in the highlands of the state of Rio de Janeiro experienced unusually heavy rainfall of 258 millimetres in three hours. Severe flash floods and subsequent landslides led to the deadliest landslide disaster ever recorded in the city, with 231 fatalities (Alcântara et al. 2022).
Floods in Ecuador, March 2020	In March 2020, Indigenous communities in Sarayaku were flooded following a historic storm in the Ecuadorian Amazon. Amid the COVID-19 pandemic, the floods destroyed infrastructure such as bridges, homes, schools, and gardens for growing food and medicine (Sarayaku 2020).

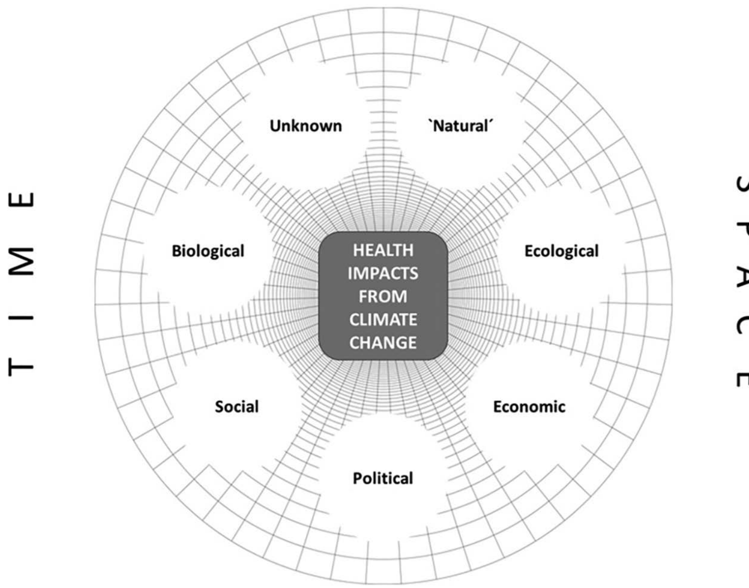
Source: Authors.

community of beings' (Cullinan 2003, p. 203). In line with this reasoning, Tănăsescu (2022) used the term 'Ecocene' to denote an era that is no longer solely about humans, but about accommodating, making peace with, and negotiating with everything that is non-human. This shift in focus away from human-centred to ecological processes indicates, in Tănăsescu's view, the broader context in which public health is pursued. This is also emphasised by One Health and Planetary Health scientists (Myers 2017, p. 2866; Whitmee et al. 2015, p. 1978; Redvers 2021, p. 2), with Redvers (2021) distinguishing between environmental determinants of human health, ecological determinants that influence both human and planetary health, and a more ecocentric approach that considers the conditions that affect the health of the planet as a whole (i.e., planetary determinants of health). Such work offers an invitation to expand the WHO's 1946 definition of health as 'a state of complete physical, mental and social well-being and not merely the absence of disease and infirmity' in relation to climate change.

In this context, 'natural' factors,[5] that is physical, biological, environmental, ecological, and planetary factors, should be analysed in conjunction with socio-political-economic dimensions that determine the health impacts of climate change. In Figure 2.1 we present a visualisation to assist researchers and policymakers in examining how factors within natural, biological, ecological, social, economic, political, and other previously unknown dimensions do not merely add up to affect health, but also interact in complex ways. This illustration also shows how these interactions span temporal and spatial dimensions, indicating that health impacts are produced and materialise in the past, present, and future, influenced by factors that overlap with acute, persistent, and chronic issues and evolving across geographical scales from local to global.

As Figure 2.1 illustrates, climate-related health impacts are not solely caused by natural disasters. Changing ecosystem conditions also make vector-borne diseases, such as malaria, and water-borne diseases, such as diarrhoeal diseases, more frequent. In the case of the floods in Bangladesh in 2022, for example, the WHO (2022) had recorded 2,492 cases of illness and injuries by 20 June, including instances of near-drowning, injuries, lightning, acute watery diarrhoea (AWD), skin, respiratory and eye infections with further outbreaks of disease expected after the water receded. In the case of the 2022 floods in Pakistan, the country was set back in its efforts to combat malaria (WHO 2023). In addition to these natural, physical, biological, and ecological dimensions that shape the health impacts of extreme weather events, people also vary in their ability to protect themselves from and deal with the health consequences.

Impacts from extreme weather events can exacerbate existing socio-economic vulnerabilities, with heatwaves, for instance, affecting people differently depending on their housing conditions, access to air conditioning, and the efficiency of emergency services. Floods, meanwhile, have a particularly severe impact on those with limited resources to cope with the loss of homes, jobs, or farmland, forced relocation, or the interruption of children's education. It becomes difficult to afford nutritious food or medical care, and on top of this, social services can be disrupted and public infrastructure destroyed, which can trigger famine, migration, and conflict (cf. Jungmann



Source: Authors.

Figure 2.1 Multidimensional understanding of health amid climate change

2021, p. 15). The 2020 floods in Ecuador affected the Indigenous Sarayaku people, who—already struggling with the COVID-19 pandemic—had long been neglected by the state. The 2022 floods in Bangladesh hit those affected by long-standing inequalities related to race, ethnicity, religion, gender, and age the hardest (Chakraborty et al. 2024; *The Guardian* 2023). The results were drownings, injuries, lightning strike-related consequences, snake bites, shortages of drinking and bathing water, water-borne diseases, an increased disease burden among vulnerable people, a rising prevalence of mental health issues, food insecurity, and disruptions to health services. Health status, mental health, ecosystemic changes, poverty, inequalities, economic hardship, and the breakdown of infrastructure interacted very closely.

Moreover, health impacts from extreme weather events are not only caused directly by climate factors, but they are enabled also from harmful practices in the construction and extractive industries. For instance, the 2022 floods in Bangladesh were enabled not only by the country's topographical characteristics including its extensive flood-plains formed by the Ganges, Brahmaputra, and Meghna rivers (80% of the country is floodplain), but also by deforestation, soil erosion from agriculture, and the damming of rivers (Human Rights Watch 2023; *The Guardian* 2023). Similarly, the 2024 East African floods were driven not only by human-induced climate change but also by rapid urbanisation, resource scarcity, and activities such as deforestation and agriculture (World Weather Attribution 2024). In Petrópolis, Brazil, unplanned urban growth on steep slopes, vegetation removal, and inadequate controls also contributed to flash flooding (Alcântara et al. 2022). In this context, construction, deforestation, agriculture, and other extractive industries are significant political-economic factors driving the health impacts of climate change. Considering multiple levels of health analysis into Environmental Impact Assessments (EIAs) and Strategic Environmental Assessments (SEAs) could be a strategy to mitigate the harmful impacts of extractive activities (Olalekan et al. 2020). In practice, however, this strategy has often proven problematic: these assessments frequently become formal tools to legitimise state-led extractive agendas (Fiske 2017), neglecting viable environmental, political, and economic alternatives.

Such debates regarding the influence of harmful industries on climate-health dynamics underscore the critical role of political action that tackles structural factors. There is a growing recognition that it takes dedicated political initiatives, measures, and policies to address the health impacts of climate change. International organisations have established knowledge hubs such as the WHO's focal point for climate and health (WHO 2021a), and the European Commission (EC) and the European Environment Agency (EEA) have launched the European Climate and Health Observatory (ECHO) (EC 2020; EEA 2021; ECHO 2023). Moreover, an emerging legislative body linking environmental and health aspects is evolving (see LSE 2022; Wu 2021): Some countries are integrating health-related goals and measures into climate legislation and, vice versa, incorporating environmental and climate considerations into health legislation. In 2021, 86% of countries included health concerns in their climate protection targets (Romanello 2022, p. 1622), and there are also calls to include climate protection as a fundamental right in constitutional law (for Austria, see Bioethikommission 2022).[6]

Furthermore, policy problems are increasingly framed in terms of health and climate. Echoing the plea for health-in-all-policies (Hall & Jacobson 2018, p. 364), One Health and Planetary Health scholars have called for governments to develop, implement, and assess 'ambitious, integrated policies to address the social, economic, and environmental determinants of health' (Whitmee et al. 2015, p. 1978; cf. de Castañeda et al. 2023; Haas et al. 2023; Batawalage et al. 2023). Here, we believe that it is useful to distinguish between precautionary, preventive, and adaptive measures. Precautionary measures are enacted even in the absence of full scientific certainty to prevent anticipated harm, and also because risks can become unmanageable once triggered. In contrast, preventive measures focus on addressing recognised risks, while adaptive measures respond to impacts that have already occurred. Environmental health scholars have long argued that a precautionary principle should shape a new public paradigm in terms of 'a set of guidelines that contend that society should take preventive action in the face of uncertainty in order to safeguard human health' (Mayer et al. 2002, p. 575; Brown 2007). Yet conversations about precautionary[7] and preventive measures related to climate and health remain sparse, while adaptation policies have garnered some attention. Jungmann's (2021) Climate Change Health Adaptation Index (CHAIn), for example, gauges countries' readiness to adapt to health impacts posed by climate change, factoring in risk recognition, adaptive capacity, and adaptation efforts. At the same time, the author cautions that these adaptation measures may carry the risk of unintended side effects.

Political initiatives aimed at mitigating the health impacts of climate change can have unintended side effects if the complexity of the situation is not sufficiently considered (cf. Wagenaar & Prainsack 2021; Wagenaar 2007; Prainsack 2023). Adaptation initiatives targeting heatwaves, drought, and desertification can exhibit such unintended consequences. For example, the provision of air conditioning in response to heatwaves can increase the demand for energy from fossil fuels and thus exacerbate 'the root problem of climate change' (Jungmann 2021, p. 29), which in turn has knock-on impacts on health. Conversely, improved water harvesting technologies can not only provide immediate relief during periods of drought and desertification but also reduce water-related health risks and support more sustainable management of natural resources in the long term.

People affected by the adverse health impacts of flooding have gained insight into the different dimensions that need to be considered when responding to the complex interactions between climate and health. The people affected by the 2023 floods in Carinthia (Austria) were keenly aware of how various factors interacted to create the situation.[8] Government-initiated projects to assist municipalities, communities, and residents in preparing for heavy rainfall events focused on housing planning, community flood defences, and citizen preparedness (Umweltbundesamt 2020). Despite these efforts, the residents of Guntschach expressed dissatisfaction with the political support at the municipal, state, and federal levels—arguably because they recognised that these measures did not get to the root causes of the problem. Residents pointed to factors such as soil sealing[9] in neighbouring villages, which they believed contributed to the increased flooding but were not adequately addressed (*Der Standard* 2024).[10] They criticised the political responses for failing to sufficiently consider the interacting factors that led to the flooding (cf. *Die Zeit* 2023; BML 2024) and knock-on health impacts—factors/dimensions that can have an impact across temporal and spatial boundaries.

When the impact of a single weather event does not stop at political borders, spatial interdependencies are becoming tangible. The inhabitants of villages such as Guntschach feel the health repercussions of floods that have been exacerbated by soil sealing in neighbouring areas. Moreover, as floods often affect more than one country, flood and water management in one country can affect the severity of flooding in another. These spatial interdependencies become more intricate when intertwined with global inequalities, as seen in situations where anthropogenic climate change originates in one area but influences populations in far-off locales. In 2022, floods in Bangladesh and Pakistan claimed thousands of lives and displaced millions of people. Despite being low-emission countries—Bangladesh produced only 0.25% of the world's total greenhouse gas emissions in 2021 and Pakistan accounted for less than an eighth of the per capita emissions of the US and a third of the emissions of the UK in 2020 (*The Guardian* 2023)—they faced widespread devastation from increasing extreme weather events such as flash floods. These countries are in a position of utter dependence on global efforts to mitigate climate change, particularly those of high-emission industrialised nations. This situation highlights the unequal distribution of disease burdens globally, which has historically been shaped by the interplay of violence, power, and colonialism (King & Koski 2020; Affun-Adegbulu & Adegbulu 2020; Hommes et al. 2021). As shown in the illustration (see Figure 2.1), the health impacts of climate change stem from chronic, persistent, and acute problems and are unevenly distributed across global, national, and local scales.

The illustration—depicting how various factors influencing health amid climate change interact across time and space—could be a helpful orientation for both policymakers and researchers. For the former, this figure could help to avoid the trap of reductionist problem framings, and the associated problems of solutions remaining within single policy fields, thereby encouraging integrated or at least coordinated action across multiple policy areas. For researchers, it could help locate existing evidence and identify research gaps, while prompting an exploration of methodological approaches that can yield insights for effective policy interventions. In this context, natural, biological, ecological, and socio-political-economic dimensions should be treated as analytical categories in climate-health research, serving as integral components of the situation or problem being studied. The following section examines how employing a mixed-methods approach that integrates inductive, qualitative, and transdisciplinary research can enhance our multidimensional understanding of health in relation to climate change.

2.3 How to research complex interactions? Mixed approaches, qualitative research, and transdisciplinarity

2.3.1 Unpacking the Politics Behind Evidence

Health effects from climate change are the result of a complex network of different interconnected and interacting factors that have not yet been fully explored. To date, much of the empirical work investigating the effects of climate change on health has consisted of quantitative model predictions (Whitmee 2015, p. 2018; *The Lancet Planetary Health* 2021; Betts & Sawyer 2015). As outlined in Table 2.2, these initiatives show that modelling work has addressed both the direct health impacts of climate change and those stemming from shifting ecosystem conditions. However, relatively little attention has been paid to the socio-political-economic factors that influence the health impacts of climate change.

Quantitative assessments of the health impacts of climate change are not ideal for capturing the interplay of the various social, economic, and political factors that influence these impacts. Whitmee et al. (2015, p. 1976) argued that '[m]any effects of global environmental change are difficult to quantify because they are mediated through complex systems that might have feedback loops and non-linear relationships between environmental change and health outcomes'. This raises the question of how mixed methods approaches that include qualitative methods could help to understand the complexity of tertiary health impacts specifically. Could such approaches improve

Table 2.2 Climate-health modelling

Initiative	Description
Coupled Model Intercomparison Project (CMIP), launched in 1995 by the Working Group on Coupled Modelling (WGCM) of the World Climate Research Programme (WCRP)	• Collaborative initiative to improve our understanding of climate change. • Brings together computer-based coupled climate models, which simulate complex interactions between different components of the Earth, such as the atmosphere, oceans, land, and ice. • Serves as a crucial data infrastructure for the Intergovernmental Panel on Climate Change (IPCC) and various national and supranational climate assessment initiatives (CMIP 2023; *The Lancet Planetary Health* 2021; *The Lancet* 2014).
Inter-Sectoral Impact Model Intercomparison Project (ISIMIP), launched in 2012 by the Potsdam Institute for Climate Impact Research (PIK) and the International Institute for Applied Systems Analysis (IIASA)	• Engaging 100 modelling groups worldwide by 2023. • Integrates socio-economic factors into the analysis of factors influencing the impacts of climate change and specifies these impacts in different sectors such as water, lakes, forests, and biodiversity at both global and regional levels. • Includes health-related issues such as temperature-related mortality, vector-borne and waterborne diseases, and food security and nutrition (ISIMIP 2023).
Environment and Health Modelling Lab (2023), at the Department of Public Health, Environment, and Society at the London School of Hygiene & Tropical Medicine	• Led by a multidisciplinary team of researchers specialised in biostatistics, environmental epidemiology, data science, statistical data processing, climatology, and other fields. • Develops pioneering innovative study designs, statistical methods, and modelling techniques for research on environmental health risks. • Has a specific focus on projecting the health effects of climate change. • Provides analysis of the time- and location-specific implications of temperature variations on health.
Special issue of *The Lancet Planetary Health* from 2021, titled: 'Taking globally consistent health impact projections to the next level' (Rocklöv et al. 2021; for a participatory modelling initiative, also see Olabisi et al. 2018)	• Analyses harmonised data and simulation protocols from ISIMIP. • Explores the specific health consequences of rising temperatures and disease spread across diverse locations. • Discusses the risks posed by specific vector-, food-, and water-borne diseases. • Also addresses occupational health risks such as anticipated declines in labour supply and productivity.

Source: Authors.

understandings of how the health impacts of climate change unfold unevenly across socio-spatial divides? McMichael and Lindgren (2011, p. 410) underscore that people's vulnerability to the health effects of climate change is contingent upon their geographical and social positioning. For instance, the Notre Dame Global Adaptation Initiative ND-GAINs ranking highlights general health risks across various sectors at the national level. Within this framework, when assessing water risks—specifically the vulnerability of freshwater supplies to climate change—India ranks 9th most vulnerable among 169 countries, Mexico 59th, and Austria 136th (GAIN 2023). However, preconceived categories such as people's national location are not enough, as we do not know how socio-spatial divides play out in people's everyday lives and what categories of difference lie behind the emerging areas of inequality that need to be addressed.

Insights garnered from everyday experiences may offer pathways to a better understanding in two ways. First, by enriching our understanding of how people perceive, experience, and understand the health impacts of climate change across socio-geographical boundaries. Second, these insights may shed light on how people experience the complex interactions between natural, biological, ecological, and socio-political-economic dimensions in their lives. Additionally, they may reveal other, previously unknown, unaccounted-for dimensions that influence, amplify, or limit the health impacts of climate change. While analysing the causal relationships between predefined categories may prove insufficient, an inductive qualitative research approach could yield unexpected results that recognise the complexity of the situation. Situational Analysis, which complements Constructivist Grounded Theory, stands out as a suitable approach because it breaks downs the division between a phenomenon and its context (Clarke et al. 2022). This method enables a holistic examination of all entities involved, encompassing individuals and groups as well as additional factors like meaning, power dynamics, material resources, and the involvement of non-human actors in a specific situation (Kalenda 2016; Timmermans & Tavory 2012; Charmaz 2006).[11] Thus, inductive as well as abductive approaches such as Situational Analysis offer the potential to integrate existing knowledge about how people perceive environmental changes, experience related health impacts, and navigate complex socio-political-economic dynamics within a transdisciplinary approach.

2.3.2 The Need for Transdisciplinary Research

Qualitative social science can play a crucial role in bringing to the fore a broad range of evidence on how people experience the health impacts of climate change. Such evidence can be gathered, for example, from civil society, Indigenous peoples, and personal accounts of affected communities. This is particularly important given the historical context where vested interests opposed to climate action, such as oil companies, have actively undermined scientific knowledge. They have disingenuously argued that alternatives to oil would be economically disastrous (Dembicki 2022). A group of scientists with close connections to the oil industry misled the public about global warming, tobacco smoke, acid rain, and insecticides (Oreskes & Conway 2010). There is an urgent need to scrutinise, challenge, and change the underlying politics of evidence: this could be achieved by shifting the burden of proof to proponents of extractive activities such as oil drilling and mineral extraction, and by engaging a broad range of stakeholders in efforts to protect human health and the environment (Mayer et al. 2002, p. 117; Fiske 2023). Such calls for integrating perspectives, experiences, and knowledge from various stakeholders at local, national, and international levels have also been articulated in the field of climate and health in recent years by The Lancet Countdown to Health and Climate Change and the Rockefeller Foundation-Lancet Commission on Planetary Health (Romanello et al. 2023, p. 2353; 2022, p. 1622; Whitmee et al. 2015, p. 2018; cf. Myers 2017).

But what could transdisciplinary climate and health research look like? Sustainability scientists have described transdisciplinarity as a third epistemic pathway beyond the binary emphasis on either scientific research or practical application; one that involves 'research collaborations among scientists from different disciplines and non-academic stakeholders from business, government, and the civil society to address sustainability challenges and develop solution options' (Lang et al. 2021, p. 26; cf. Lang et al. 2012). It shares characteristics with other collaborative research approaches such as community-based, interactive, and participatory approaches and encounters similar challenges—including the fact that collaborating partners may interpret the problem at hand differently, that they may lack a shared vocabulary for discussing the topic, and that they adhere to distinct forms of organising their work.

One of the key questions thus is how collaborators perceive, experience, and address the challenges arising from the interactions between climate and health. Engaging flood-affected residents in Guntschach, Austria, in research collaborations with scientists could generate valuable knowledge. Likewise, partnering with business, government, and civil society stakeholders from flood-prone regions such as Bangladesh and Pakistan could help rethink policy interventions, strengthen institutional commitments, and foster global responsibility. In their analysis of the 2023 floods in Bangladesh, scholars underscored the importance of coordinating among various stakeholders, such as global players, national governments, local governments, civil society organisations, the private sector, and research institutions. The 2021 floods in Germany were attributed to a lack of responsibility on the part of the federal states in addition to inadequate risk maps, inefficient crisis communication, and insufficient siren infrastructure (see e.g., Decker et al., 2021). Regarding the 2023 floods in Bangladesh, scholars have also highlighted the need to collect knowledge about vulnerabilities and local needs, and to integrate local knowledge into policies, plans, and decision-making processes (LSE 2023; Chakraborty et al. 2024). This means that in addition to improving early warning systems, flood hazard maps, flood monitoring tools, and nature-based solutions such as mangrove planting, reforestation, and afforestation, it is necessary to pay close attention to people's experiences during floods: what happens when people lose their homes? How do they depict these processes (e.g., drawing community maps)? How do they observe environmental change over time (e.g., marking high water levels during floods)? What kind of health impacts do they experience, including mental health challenges such as dislocation, Post-Traumatic Stress Disorder (PTSD), or difficulty getting health needs met during times of crisis? What kinds of local knowledge do they apply (e.g., Indigenous knowledge on tidal river management, changes in building or community design)? Such collaboratively created knowledge can be of utmost importance for identifying possible interventions against the health effects from climate change.[12]

There is considerable potential for researchers, scientific communities, and academia to address the most pressing health challenges of the twenty-first century through transdisciplinary collaboration. At the same time, however, transdisciplinary research faces significant institutional barriers. Academic institutions, despite rhetoric around the importance of transdisciplinary and interdisciplinary research, still give incentives to disciplines operating in silos. Discipline-specific evaluation criteria and educational curricula that marginalise collaborative, inter-, and transdisciplinary output (cf. Frickel & Gross 2005; Frickel & Moore 2006) are still the norm in universities in most world regions. Additionally, institutional support structures, encompassing administrative services, infrastructure, and professional development opportunities, are typically tailored to traditional disciplinary research paths, lacking the flexibility required for transdisciplinary work. With only a few exceptions, funding mechanisms often exacerbate this challenge, as grant agencies and institutional funding bodies typically favour well-established disciplinary research, which discourages transdisciplinary initiatives that may seem riskier or less conventional. We argue that this fragmentation still holds in place a research culture that prioritises disciplinary depth over inter- and transdisciplinary breadth, making it difficult for researchers to engage in collaborative efforts across disciplines, fields, and sectors. A systemic overhaul is necessary to shift this culture towards integrative and co-produced knowledge, which is necessary for the advancement of transdisciplinary climate and health research.

Transdisciplinary insights, knowledge, and research can illuminate the complex dynamics among various factors influencing the health impacts of climate change. Such an understanding can also pinpoint leverage points, meaning 'places within complex systems ... where a small shift in one thing can produce big changes in everything' (Meadows 1999, p. 1; cf. Abson et al. 2017, p. 30; Lang et al. 2021, p. 32). Identifying these leverage points is crucial for devising effective strategies to address, mitigate, and adapt to the health effects of climate change. However, Abson et al. (2017) have highlighted that leverage points which are easily influenced, intuitively conceived, and seemingly 'quick fixes' are often too weak for urgent issues like the climate crisis. More impactful leverage points are typically less obvious, sometimes harder to influence, but ultimately more effective. In the realm of climate-health interventions, these may involve sustainable land use, rewilding initiatives, cultural heritage preservation, respect for socio-communitarian relations, addressing existing inequalities, legal and policy measures, and much more. Within the complex interplay of climate and health, such dynamics could serve as crucial leverage points with the potential to prevent, mitigate, or adapt to the health impacts of climate change.

Transdisciplinary approaches to understanding the multidimensional constitution of health in a changing climate hold the potential to identify profound leverage points for political interventions that may be less obvious but often prove more effective. They moreover prompt a reassessment of the strategies employed in public health delivery in safeguarding public health amidst a changing climate.

Notes

1. The Millennium Ecosystem Assessment (commissioned by the United Nations in 2000 and published in 2005) encapsulates the direct health impacts succinctly as 'flooding, heat waves, water shortage, landslides, exposure to ultraviolet radiation, exposure to pollutants' (Millennium Ecosystem Assessment 2005).
2. Here, the term 'natural' tends to refer to the primary, the term 'eco-systemic' to the secondary, and the term 'societal dynamics' to the tertiary health effects of climate change.
3. While research has established a broad correlation between convective precipitation and air temperature (Fowler et al. 2021), the recently developed attribution theory for extreme weather can show the extent to which extreme weather events can be attributed to anthropogenic climate change and/or other factors (Otto & von Brackel 2019).
4. Heatwaves are often associated with drought, poor air quality, and forest fires, which may make flash flooding more likely when rains come (WMO 2022).
5. 'Natural', written here in inverted commas, is an indicator of dynamics that may appear natural in the sense of externally given influences, but which could later be understood more deeply in their biological, ecological, socio-political-economic, and other constitution.
6. As is widely recognised, supranational entities have enacted climate change legislation, such as the European Climate Change Law (EC 2021) and the climate strategy of the African Union (2022).
7. We believe that this is a crucial starting point for scientific, political, and social action, but it requires a broader discussion that we cannot provide in this chapter.
8. In the municipality of Bad Eisenkappel, emergency aid was provided to 200 residents who were supplied with food and medicine after the access road was destroyed by the flood. In Guntschach, 70 inhabitants were isolated from December 2022 to May 2024 due to a rockfall in 2022 and landslides during the 2023 floods that washed away an emergency road. Despite predictions of increased extreme weather, Guntschach residents chose to stay, using a ferry and forest trails to leave the village.
9. Soil sealing means that natural soil is covered with materials such as concrete, asphalt, or buildings, which prevents water from infiltrating into the ground.
10. In Europe, the European Commission launched a Floods Directive in 2007 to reduce the risk of flood damage through '[i]ntegrated flood risk management [that] must focus on sustainable water management and measures that strengthen the resilience of nature and society to extreme weather events' (EC 2024).
11. Actor Network Theory is another approach for this purpose.
12. Here, it is important to note that such interventions can address both health impacts and climate change to varying degrees.

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