An analysis of climate change and health hazards: results from an international study

Walter Leal Filho, Linda Ternova, Muhammad Muddassir Fayyaz, Ismaila Rimi Abubakar, Marina Kovaleva, Felix Kwabena Donkor, Samuel Weniga Anuga, Abraham R. Matamanda, Ilija Djekic, Ibrahim Abatcha Umar, Felicia Motunrayo Olooto, Maria Meirelles, Gustavo J. Nagy, Julia May, Marta May, Eromose Ebhuoma and Halima Begum

(Author affiliations can be found at the end of the article)

Received 16 August 2021
Revised 4 January 2022
4 April 2022
Accepted 8 April 2022

Abstract

Purpose – The interconnections between climate change and health are well studied. However, there is a perceived need for studies that examine how responses to health hazards (e.g. cardiovascular diseases, ozone layer effects, allergens, mental health and vector-borne diseases) may assist in reducing their impacts. The purpose of this paper is to review the evidence on health responses to climate hazards and list some measures to address them.

Design/methodology/approach – A mixed literature review, bibliometric analysis and an original online survey were undertaken on 140 participants from 55 countries spread across all geographical regions.

Findings – The bibliometric analysis identified that most climate-related health hazards are associated with extreme weather events. However, only one-third of the investigated papers specifically analysed the connections between climate change and health hazards, revealing a thematic gap. Also, although Africa is highly affected by climate change, only 5% of the assessed studies focused on this continent. Many respondents to the survey indicated "heat distress" as a significant vulnerability. The survey also identified social determinants relevant to climate-induced health vulnerabilities, such as socioeconomic and environmental factors, infrastructure and pre-

Conflict of interest. The authors declare that the research was conducted without any commercial or financial relationships that could be considered a potential conflict of interest.

Funding. This article has not received any external funding. It was developed by the International Climate Change Information and Research Programme (ICCIRP), Hamburg University of Applied Sciences (HAW).

Data availability statement. The data sets (Questionnaire Survey) analysed during the current study are included in this published article (Table 3) and are available from the corresponding author on reasonable request.

International Journal of Climate Change Strategies and Management
Vol. 14 No. 4, 2022
pp. 375-398
Emerald Publishing Limited
1756-8692
DOI 10.1108/IJCCSM-08-2021-0090

existing health conditions. Most respondents agree that policies and regulations are the most effective adaptation tools to address the public health hazards triggered by climate change. This paper presents some suggestions for optimising public health responses to health hazards associated with climate change, such as the inclusion of climate-related components in public health policies, setting up monitoring systems to assess the extent to which specific climate events may pose a health threat, establishing plans to cope with the health implications of heatwaves, increased measures to protect vulnerable groups and education and awareness-raising initiatives to reduce the overall vulnerability of the population to climate-related health hazards. These measures may assist the ongoing global efforts to understand better – and cope with – the impacts of climate change on health.

Originality/value – The combination of a literature review, bibliometric analysis and an original world survey identified and presented a wide range of responses.

Keywords Climate change, Extreme weather, Health hazards, Bibliometric analysis, Climate change responses, Adaptation responses

Paper type Literature review

1. Introduction

It is widely acknowledged that human well-being can be influenced by various environmental factors, including climate change. Indeed, awareness about such connections dates back centuries. For example, the Greek doctor Hippocrates (around 400 BC) associated some plagues with periodic weather variations. Also, he suggested that doctors consider the annual seasons and illnesses they generate, unusual air moving conditions and water quality as variables associated with some diseases (McMichael *et al.*, 2003).

As time went by, Hippocrates was right about his observations. Moreover, his viewpoints about the influences of the environment – and of the climate – on human health appear to be accurate, particularly concerning infectious diseases (Falagas *et al.*, 2010).

The key findings from the Sixth Assessment Reports issued by the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2021) depict the seriousness of climate change as a global problem and accentuate the need for immediate interventions. In this context, global warming by roughly 1.0°C beyond pre-modern levels since the 1950s and its effects on ocean levels (Allen *et al.*, 2018), or human-induced greenhouse gas emissions leading to ocean acidification (Pachauri *et al.*, 2014), are worrying trends.

Also, there is broad recognition that climate change affects human health through four predominant components:

(1) increases in temperatures;

(2) extreme weather events;

(3) rising sea levels; and

(4) high concentrations of carbon dioxide.

These climate-related components are associated with health-related and environmental outcomes (heat-related diseases, expanding allergens, water quality-related diseases, environmental degradation or vector-borne diseases). Therefore, because of its impacts, climate change is expected to negatively influence the achievements of the Sustainable Development Goals (SDGs), especially SDG3 (Good Health and Wellbeing) and SDG13 (Climate Action), among others (Leal Filho *et al.*, 2021).

The seriousness of the impacts depends on the exposure of an individual or a specific population (Centers for Disease Control and Prevention, 2021). Moreover, climate change may affect human well-being both directly (dry seasons, floods and hot spells) and indirectly

(e.g. decreased soil fertility because of droughts, leading to crop failures), depending on ecological, social and general health determining factors (Campbell-Lendrum *et al.*, 2018).

For instance, between 1990 and 2017, the Western Pacific Region and Africa experienced rises in heat by 33.1%–36.6% and 28.4%–31.2%, respectively. In addition, because of its ageing population and high urbanisation, the European continent is quite vulnerable to heat exposure. The number of older adults suffering from heatwave exposures reached 220 million in 2018, exceeding the previous record set in 2015 (Watts *et al.*, 2019).

From 2015 to 2018, 152 countries around the globe recorded wildfires, breaking the records seen in 2001–2004 (Watts *et al.*, 2019). Also, alterations in climatic conditions promote the transmission of many infectious diseases (WHO, 2016) and, in some cases, starvation (Bell *et al.*, 2016).

This paper addresses a gap in the literature on climate change and health hazards from a global perspective. Several studies (Head, 2014; Watts *et al.*, 2015; Van Woezik *et al.*, 2016; Herring *et al.*, 2018; Awuor *et al.*, 2020) have asserted that many climate change-related factors such as extreme weather, rising surface temperatures and sea levels, melting ice and snow, on the one hand, and floods, hurricanes or droughts, on the other, create health hazards which influence the quality of life of millions of people around the world (Akhtar, 2020; Javadinejad *et al.*, 2020; Bell *et al.*, 2018). These are paralleled by economic losses, social and ecological disruptions and technological challenges (Oven *et al.*, 2012; Head, 2014; Wang and Horton, 2015; Van Woezik *et al.*, 2016), which are often worsened by a lack of adequate policies (Myers *et al.*, 2012), especially those which may help to reduce their risk and hazards to health (Curtis *et al.*, 2017; Wistow *et al.*, 2015).

Numerous international collaborative studies, such as the Lancet countdown, have reviewed how weather affects health and may create health hazards across the globe (Cruz *et al.*, 2020; Ebi and Bowen, 2016; Hashim and Hashim, 2016; Watts *et al.*, 2015; Costello *et al.*, 2009). For example, because of extreme heatwaves, there is a noticeable call-out rate of hospital ambulances and admission because of massive cardio-vascular problems and hyperthermia (Wang and Horton, 2015; Hajat *et al.*, 2007).

As far as the environment is concerned, phenomena such as extreme heatwaves increase soil aridity lead to reduced availability of water and may also lead to losses of biodiversity (Huang *et al.*, 2013; Schultz *et al.*, 2015; Reid *et al.*, 2016; Curtis *et al.*, 2017; Rossiello and Szema, 2019).

Changes in temperature and precipitation may also increase the risks associated with vector-borne diseases such as rift valley fever, dengue fever and malaria, among many others (Curtis *et al.*, 2017; Rossiello and Szema, 2019). In addition, mental health is also threatened in the long term by physical morbidity because of exposure to phenomena such as floods (Mason *et al.*, 2020).

Table 1 summarises the main climate stressors and associated health hazards.

Table 2 shows an overview of some of the literature on the health impacts of extreme climate events.

Departing from the fact that research on the connections between climate change and public health is essential in deciding what adaptation measures are needed, this study aims to review the evidence on health responses to climate hazards and presents the results of a world study where a wide range of responses was identified and presented, along with some of the measures which may assist in implementing them.

Climate-related health hazards	*Description and references*
Cardiovascular diseases (CVDs)	Although the human body can adjust to environmental stressors, extreme temperatures and air pollution increase the risk of developing cardiovascular diseases (Giorgini *et al.*, 2017) A study developed in the UK and India indicated that a combination of active transportation and replacement of high carbon dioxide emitting vehicles with low carbon dioxide emitting vehicles results in fewer Years of Life Lost (YLL) from Ischemic Heart Diseases (IDH) by approximately 15–17% on average (Woodcock *et al.*, 2009) High temperatures affect the respiratory systems by making the air dry, complicating blood flow and at times the association with air pollution places citizens at risk (Demain, 2018)
Ozone layer effects	Depending on the exposure to radiation and the geographical distribution of the population, the depletion of the ozone layer and particulate material impacts health leading to an increased number of premature deaths (Orru *et al.*, 2017) The increased exposure to ultra-violet radiation poses both pros and cons to human health. An advantage is the production of Vitamin D in the skin and sterilisation of the freshwater used for drinking and sanitation. Nevertheless, at the same time, the disadvantage includes conditions like cataracts, skins cancers like melanoma and activation of infectious diseases (Andrady *et al.*, 2017)
Consumables/Greenhouse emissions (GHG)	The excessive use of coal, oil and gas increases the number of greenhouse fumes that eventually add together to magnify global warming, disrupting the human body's well-being and mental health (Barrett *et al.*, 2015) A study developed in the UK and India showed that combining active travel and low emission transport vehicles would provide higher health benefits (Woodcock *et al.*, 2009)
Allergens	Global warming has caused widespread allergens that trigger many allergic responses, generating autoimmunity in formerly disease-free populations and aggravating allergic respiratory diseases. Moreover, it changes the antigenic profile, overpowering the body's ability to bear it "Over the Counter" (OTC) use of antibiotics leading to antimicrobial resistance has further worsened the scenario. This microbial imbalance has promoted infectious diseases (Ray and Ming, 2020)
Maternal/foetal health	A systematic review (Kuehn and Mccormick, 2017) showed that the climate change effects were compared with the health of pregnant women and their foetuses, suggesting that the warming climate has led to a rise in the population's frequency of heatwaves with adverse effects on maternal and foetal health. It has affected the gestational age and the foetal well-being in a mother's womb and impacted the child's health after delivery in the form of neonatal stress. A temperature of 42°C is considered extraordinarily high Exposure to such heat has consequently shown an increase in preterm deliveries, which is birth before the completion of the gestation period (generally between 37 and 42 weeks). The second most common outcome of heat exposure is the baby's low birth weight at the time of delivery, leading to a rise in the Neonatal Intensive Care Unit (NICU) because of heat inflicted stress, sometimes leading to death (Kuehn and Mccormick, 2017)
Mental health	A systemic review (Palinkas and Wong, 2020) identified various factors affecting mental health because of climate change and duration (acute, sub-acute and long-lasting/chronic) The critical or acute phase, including climate-related disasters that spread rapidly on a large scale, induces psychological conditions such as major

(*continued*)

Table 1.
Summary of climate-related health hazards

Climate-related health hazards	*Description and references*
	depression, anxiety, stress, post-traumatic stress disorder (PTSD) and insomnia because of the stressor. It persisted for several months and sometimes up to a year Subacute conditions (like heat waves) are associated with violent and illicit manners in a person It is leading to a surge in the cases of suicides and physical abuse in adult men particularly. Increased temperatures also affect thyroid function, reducing hormone activity and causing thyroid diseases that clinically present as tiredness and flawed thinking. It was estimated that temperatures above 30°C promoted psychological conditions by 0.5%, and every one °C warming within five years increased this rate by 2%. This usually occurs as a response at two levels: (1) A physical-level response is stimulated by heat, trauma, scarcity of food and illnesses (2) A community-level response because of socioeconomic damage to the environment and disrupted surroundings The predominant psychological effects because of fear, lack of knowledge of climate change and its consequences result in a variety of mental health conditions which includes psycho-terratic syndrome (the emotions through which a human relates to his planet) and the following disorders like eco-anxiety (worrisome state concerning future of the Earth), eco-paralysis and solastalgia; an emotional form of existential crisis because of environmental distresses The young generation is a high-risk population for such conditions (Palinkas and Wong, 2020)
Vector-borne diseases	Climate change is critical in spreading vector-borne diseases, significantly impacting mosquito-borne diseases (MBD). Besides, the lack of health facilities makes the human population much more susceptible to the outspread of MBD. High temperatures and humid environments favour the spread and regrowth of these vector-borne diseases (both consequences of global warming) This situation is worsened when the affected population faces a scarcity of health facilities, inadequate treatment options and damage to available resources by environmental catastrophes (Leal Filho *et al.*, 2019) Climate change and public health research are fundamental in deciding what adaptation measures are needed

Table 1.

2. The need for adequate responses to health hazards related to climate change

Anthropogenic activities account for most greenhouse gas emissions, resulting in climatic changes, including erratic weather patterns and increases in extreme climate events. Their effects severely impact the global population, targeting public health (Tong and Ebi, 2019). The World Health Organization (WHO) estimates that between 2030 and 2050, climate change impacts could lead to about five million additional deaths globally, from diarrhoea, malaria, malnutrition and heat stress alone, plus direct damages to health-care systems, estimated at $2–4bn per annum (WHO, 2018). Because of their stressed and weak health-care management and existing health inequalities, developing countries are more likely to be severely affected by climate change than developed countries (Patz *et al.*, 2007). Thus, health risks and hazards are predominant in developing countries where communities are highly

Title	*Focus*	*Author(s)*
Impact of extreme weather events and climate change on health and social care systems	Impacts on health and social care systems	Curtis *et al.* (2017)
Impacts on health of climate extremes	Focus on infectious diseases and the effects of extreme weather events on mortality	Hales *et al.* (2003)
Extreme events as sources of health vulnerability: Drought as an example	Focus on drought and health vulnerabilities	Ebi and Bowen (2016)
Health impacts of extreme events	Focus on the relationship between climatic elements with the various diseases in Khoozestan province	Javadinejad *et al.* (2020)
Extreme Weather Events and Human Health: A Global Perspective	This book provides insight into different extreme weather events in various countries	Akhtar (2020)
Changes in extreme events and the potential impacts on human health	Focus on changing extreme weather events and examples of the possible effects on human health and infrastructure	Bell *et al.* (2018)
Climate Change, Extreme Weather Events, and Human Health Implications in the Asia Pacific Region	Focus on Asia	Hashim and Hashim (2016)
Climate change, extreme weather events, air pollution and respiratory health in Europe	Focus on weather extremes and respiratory health effects in European countries	De Sario *et al.* (2013)
Mental Health and Weather Extremes in a South-eastern US City: Exploring Group Differences by Race	Mental health and weather extremes in the USA	Mason *et al.* (2020)
Effect of Extreme Weather Events on Mental Health: A Narrative Synthesis and Meta-Analysis for the UK	Mental health and weather extremes in the UK	Cruz *et al.* (2020)
Health Effects of Climate Change-induced Wildfires and Heatwaves	Health effects of wildfires and heatwaves	Rossiello and Szema (2019)
The potential impacts of climate variability and change on health impacts of extreme weather events in the United States	Extreme weather conditions in the USA and health impacts	Greenough *et al.* (2001)
Impacts of Extreme Events on Human Health. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.	Extreme weather events in the USA and health effects	Bell *et al.* (2016)
Critical Review of Health Impacts of Wildfire Smoke Exposure.	Wildfire smoke exposure and health effects	Reid *et al.* (2016)
Managing the Health Effects of Temperature in Response to Climate Change: Challenges Ahead	Temperature and health impacts	Huang *et al.* (2013)
Climate Change and Human Health Impacts in the United States: An Update on the Results of the US National Assessment.	Weather extremes in the USA and human health impacts	Ebi *et al.* (2006)

Table 2.
Overview of some of the literature on the health impacts of extreme climate events

susceptible to climate-sensitive diseases, respiratory, vector and water-borne diseases (Seneviratne *et al.*, 2017; Smith *et al.*, 2014; Watts *et al.*, 2018).

The literature indicates other diverse climate-related health consequences, including heatstroke, asthma, preeclampsia, preterm birth, low birth weight and cardiovascular diseases (Yang *et al.*, 2020; Poursafa *et al.*, 2015). For example, during the heatwave of the summer of 2003, more than 70,000 excess deaths were recorded in Europe (WHO, 2018). Also, the rate of social conflicts among individuals that results in intentional injuries and mortality is exceptionally responsive to temperature changes, which affect the underlying socioeconomic conditions and individual level of aggressiveness (Parks *et al.*, 2020; Palinkas and Wong, 2020). In the Global South, the lack of appropriate responses to climate change vulnerability has created gaps in responding to climate-induced health hazards.

Appropriate policies and responses are vital in preventing the many health hazards related to climate change and the associated climate-induced illnesses. The WHO and the IPCC have developed blueprints to help adapt to the health impacts of climate change (Swinburn *et al.*, 2019; Pachauri *et al.*, 2014). The Paris Climate Agreement was also signed to prevent a rise in global temperature, thus reducing health risks. However, global temperature continues to rise (Hoegh-Guldberg *et al.*, 2019; Rocklöv and Dubrow, 2020). The United Nations (UN) SDGs were also developed to target climate change (Omisore, 2018). The slow progress in meeting these goals has prompted specific health-related interventions to deal with climate change health hazards (Omisore, 2018).

Considering the features of the health sector and the dynamics of communities when planning adaptation strategies is vital to protect vulnerable populations. There are several barriers to access to quality health-care services in developing countries, including extended distances to health centres, underfunding, lack of highly qualified physicians and hospital beds, lack of health awareness and high illiteracy levels among the population (Gilbert and Dako-Gyeke, 2018). Public health institutions are also often constrained by the uncertainty of climate change impacts, lack of financial resources, access to and use of technologies, insufficient social capital, personal knowledge and perceptions, the prioritisation of more immediate public health challenges and fragmented institutional arrangements (Austin *et al.*, 2019; Fernández-Niño *et al.*, 2018).

At the entire value-chain of public health services, the knowledge gap on the health impacts of climate change and institutional barriers needs to be addressed to ensure appropriate action towards climate change adaptation (Austin *et al.*, 2019; Fernández-Niño *et al.*, 2018). Therefore, it is crucial to strengthen action and strategies to address health concerns associated with climate change, enhance attention to the needs of vulnerable populations and educate the public about the threats that climate change poses to human health. In addition, climate change should be mainstreamed into national-level health policies to promote primary health advancement through sustainable government funding and resource support (WHO, 2018). Inappropriate responses to climate change could result in maladaptation and predispose vulnerable populations to extreme health impacts.

Observational studies are carried out to understand the relationships between meteorological factors and disease toward curbing infection spread (Byrd *et al.*, 2020; Brubacher *et al.*, 2020). Models are designed to predict future events because of climate change based on the available data. However, these models are not always accurate because of unpredictable variables that need to be considered. Therefore, control and prevention methods are more reliable. Increased diagnosis and treatment of disease is the best way to control the spread of disease. Other interventions include ensuring a population is vaccinated for the specific climate-related disease, providing clean water and sanitation and reducing heat produced in an area to prevent temperature spikes (Rocklöv and Dubrow, 2020).

3. Methodology

Consistent with the aims of this study, which is to analyse the interconnections between climate change and health and review the evidence on health responses to climate hazards, a set of two methods were used: a bibliometric analysis and a world survey.

The bibliometric analysis was performed by linking climate change and health hazards. The direct application of keywords such as "climate change and health" and "climate change responses and health hazards" revealed hundreds of thousands of papers in different scientific search engines (i.e. in the ScienceDirect search, using the keyword "climate change and health", reported over 200,000 results). Based on the dispersion of these publications (research and review articles, book chapters, conference papers and editorials), the authors focused their attention only on research articles, sorting them by relevance. Also, to make the literature review more relevant, manuscripts indexed between 2019 and 2021 on the first page of the search engine have been analysed. The final set comprises 40 papers.

All articles were further processed in the geographic region in which the research was focused. Both climate change effects (global warming, extreme weather conditions, precipitation patterns and other natural disasters) and the health dimensions were analysed. Finally, the authors ranked papers as follows: 1 – health hazards connected with climate change only; 2 – health hazards indirectly connected with climate change (with literature discussion); 3 – health hazards connected with climate change (with research results); and 4 – health hazards connected with climate change with straightforward responses.

In parallel, the authors used a systemic analysis of journal publications that addressed the impact of climate change on public health through the term co-occurrence analysis provided by VOSviewer. Some of the health hazards considered included cardiovascular diseases, respiratory diseases, mental disorders, food-borne diseases, water-borne diseases, malnutrition and insect-borne diseases. Journal articles published between 2020 and 2021 were selected and examined from scientific databases such as Web of Science and Science Direct.

The second method used was a questionnaire designed, pre-tested and, subsequently, distributed online to understand better individual experiences and opinions of climate change-induced health challenges. The questionnaire was also distributed to the e-mail list of the European School of Sustainability Science and Research and the International Climate Change Research and Information Programme. They involve students, researchers and practitioners across disciplines and countries.

4. Results and discussion

4.1 Results of the bibliometric analysis

The results of the bibliometric analysis are shown in Figure 1.

Based on the bibliometric analysis, most health hazards are associated with extreme weather (43.5%), such as droughts, frosts, storms, heatwaves, wildfires or global warming (40.3%), mainly in terms of higher temperatures than average. This categorisation concurs with the IPPC reports, emphasising that most adverse changes in the atmosphere caused by climate alteration are changes in global mean temperatures and global water cycle deviations, causing precipitation pattern variations between wet and dry regions and the occurrence of extreme weather (Stocker *et al.*, 2013). According to the WHO, the health hazards associated with climate change include cardiovascular diseases, respiratory diseases (including aeroallergens), mental disorders, food-borne diseases, water-borne diseases, malnutrition and undernutrition and insect-borne diseases (WHO, 2018). Regarding the types of health hazards, the authors mostly covered cardiovascular diseases (31.1%), followed by water-borne diseases (26.7%) and respiratory diseases (22.2%).

When it comes to the connections between the two dimensions, (i) climate change and (ii) health hazards, only one-third of the papers researched both, while almost another third (28.9%) only mention the potential correlation between health hazards they analysed and climate change. In comparison, 22.2% supported their research of one dimension with a literature discussion of the other. Finally, only 15.6% of papers investigated health hazards related to climate change, with clear responses on combating their effects. The analysis of the geographic focus showed that authors tried to examine this phenomenon on a global scale (28.9%), followed by studies on climate impact on the health of European citizens (24.6%). Although Africa is recognised as a region highly affected by climate change, only 5% of studies investigated Africa, while no studies covered South America. Co-authors were mainly from Europe (34.0%), followed by Asian and North American scholars (with 20.0% each) and Australia (including New Zealand) participating in 14.0% of papers.

4.2 Results of the survey

The survey questions (Qs) were completed by 140 participants: 58.6% males, 40.7% females and one gender-neutral participant (0.7%). Table 3 summarises the descriptive statistics of study participants. A total of 55 countries worldwide were represented, with most of them residing in Africa (32.1%), Europe (28.6%) and Asia (21.4%), while the rest reside in North America (9.3%), Oceania (4.3%) and Latin America and the Caribbean (4.3%).

Figure 2 shows the countries which took part in the study. The participants were mostly aged 39–48 years (30.9%), followed by those over the age of 58 years (28.1%), those aged 49–58 years (18.7%) and those aged 29–38 years (17.3%), while the youngest age group (18–28 years) was the least represented (5.0%). A vast majority (89.9%) of them have postgraduate education, followed by those with bachelor's qualifications (7.2%) and high school education (2.9%). They are mainly trained professionals (36.0%), upper management (16.5%) and lower management employees (16.5%), retirees (10.1%), students (6.5%), consultants (5.0%) and administrative staff (3.6%). About a third (33.1%) have an average monthly household income of over US$3,000, followed by those earning US$1,001–1,500 (17.6%) and those earning less than US$500 (15.4%). While only 6.5% were not under lockdown because of the COVID-19 pandemic, 48.2% and 45.3% were under full and partial lockdown, respectively.

Climate variability is associated with an escalation in several non-communicable and infectious diseases. Understanding people's experience of climate-induced health vulnerabilities can help tailor public health interventions to address the burden of public health challenges (Salata *et al.*, 2017). Hence, assessing the nexus between climate impacts and related health vulnerabilities is necessary. In response to a question about the principal climate-induced vulnerabilities, "Feeling hot" registered the least number of responses (1.4%), while a substantial portion of the respondents (36.9%) pointed to "Heat distress" as the core vulnerability. "Breathing problems" were considered the second principal challenge (19.1%). Heat stress is acknowledged as one of the consequences of climate change in urban areas. Its impacts cut across the economy, society, environment and human health. Given the escalating rate of urbanisation and economic development in urban areas, heat stress would likely increase (Guo *et al.*, 2017).

Moreover, Tawatsupa *et al.* (2012) argue that heat stress can interfere with an individual's daily activities, such as sleep, work, domestic activities and exercise, with implications for their health and well-being outcomes (emotions and life satisfaction). Furthermore, breathing problems can be attributed to various issues such as asthma, chronic obstructive pulmonary disease and temperature increase, among others.

Gender	*No.*	*(%)*	*Age*	*No.*	*(%)*
• Male	82	58.6	• 18–28 years	7	5.0
• Female	57	40.7	• 29–38 years	24	17.3
• No answer	1	0.7	• 39–48 years	43	30.9
Region of Residence			• 49–58 years	26	18.7
• Africa	45	32.1	• Over 58 years	39	28.1
• Asia	30	21.4	*Level of education*		
• Europe	40	28.6	• High school	4	2.9
• Latin America and the Caribbean	6	4.3	• Bachelor	10	7.2
• North America	13	9.3	• Postgraduate	125	89.9
• Oceania	6	4.3	*Occupation*		
Average monthly household income			• Administrative staff	5	3.6
• Below $500	21	15.4	• Trained professional	50	36.0
• $500 to $1,000	24	17.6	• Retired	14	10.1
• $1,001 to $1,500	14	10.3	• Upper management	23	16.5
• $1,501 to $2,000	14	10.3	• Middle management	18	12.9
• $2,001 to $2,500	11	8.1	• Junior management	5	3.6
• $2,501 to $3,000	7	5.1	• Student	9	6.5
• Above $3,000	45	33.1	• Consultant	7	5.0
Stage of lockdown at the height of the COVID-19 pandemic			• Unemployed	2	1.4
No lockdown	9	6.5	• Temporary employee	3	2.2
Full lockdown	67	48.2	• Skilled labourer	2	1.4
Partial lockdown	63	45.3	• Self-employed/Partner	1	0.7

Table 3.
Descriptive statistics of study participants

Results from Table 4, which includes the responses to five survey questions (Q1–5), show that most respondents are vulnerable to "Heat distress" and "Breathing problems", which underscore the urgency of a better understanding of climate-induced health vulnerabilities. This comes with direct implications for SDGs such as SDG3, aiming to improve all ages'

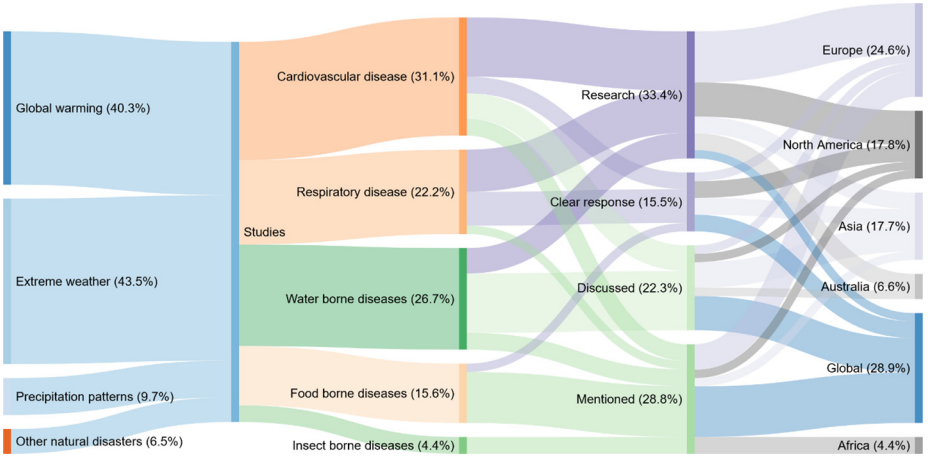

Figure 1.
Sankey chart showing the distribution of types of analysis associated with climate change and health

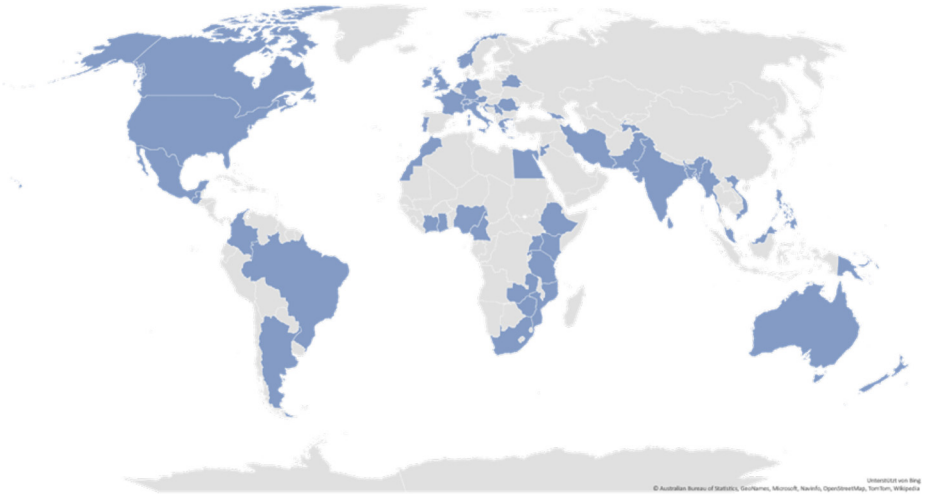

Figure 2.
Countries that took part in the survey

healthy lives and well-being. It is also consequential for SDG11 on developing sustainable cities and communities. The responses to Q1 can inform attempts to determine the scope of the climate vulnerability assessments. They also suggest some social determinants of health that need to be considered in addressing climate-induced vulnerabilities to health, such as socioeconomic factors, environmental factors, infrastructure and pre-existing health conditions. Thus, detrimental impacts on human health include reduced well-being and increasing incidences of heat-related illnesses and mortality (Guo *et al.*, 2017). In addition, aggravated heat exposure can be detrimental to physical health, including heart strokes and mental health challenges (Lemonsu *et al.*, 2015; Salata *et al.*, 2017).

In terms of climate change awareness creation, the majority of respondents (80.0%) consider "Social media" as the most effective tool, while "Religious scholars" and "Community awareness" are jointly considered as least effective (0.7%). According to the

Questions (Q)	*Responses (%)*
Q1. Have you experienced any health problems related to alterations in the climate over the past years? If so, which health problem? "Major vulnerabilities to climate change"	Not applicable: 0.7 Itching, humidity and mental stress: 0.7 None: 2.1 Feeling too hot: 1.4 Feeling too cold: 6.4 Heat distress: 36.9 Blood pressure issues: 7.1 Breathing problems: 19.1
Q2. Which of the following platforms significantly influence people's awareness about climate change in their lifestyle?	Religious scholars: 0.7 Telephone (e.g. WhatsApp): 14.3 Government agencies: 32.9 Social media: 80 Internet: 60 Newspaper: 25.7 Community awareness: 0.7 Radio: 30.7 Television: 78.6
Q3. What are the significant health hazards from the effects of climate change?	None: 0.7 Others: 1.4 Injuries and fatalities: 18.6 Nutritional shortages and food insecurity: 60 Respiratory and cardiovascular diseases: 60 Worsening air pollution and allergies: 67.9 Water and food contamination: 65 Infectious diseases: 66.4
Q4. Which populations are the most affected by public health hazards of climate change?	People in the global south: 0.7 Pregnant women: 0.7 Outdoor workers: 0.7 All of the above depending on the hazard: 1.4 None: 0.7 Residents of slums and squatter settlements: 49.3 Children: 59.3 People with underlying health conditions: 64.3 The elderly: 71.4 The poor: 88.6
Q5. Which of the following are the most effective measures for mitigating and adapting to the public health hazards of climate change?	Public health-care system that can deliver every aspect of health care: 0.7 Relevant, usable, legitimate and credible information: 1.4 Vaccinations and medical treatments: 17.1 Regulations/policies to control emissions and pollution: 80.7 Community resilience and connectedness: 60.7 Advancement of technologies: 0.7 Green infrastructure, sea walls and levers: 55.7 Health communications and outreach: 37.1 Early warning system and post-hazard responses: 67.9

Table 4.
Online survey questions (Qs) and responses

sample, the responses to Q2 help identify the effective media for creating climate awareness. The international nature of the respondents implies such views cut across nationalities and can help inform global response measures. Education is a critical aspect of the worldwide response to climate change. When people are climate literate, they understand their role in the dynamics of climate change (Donkor *et al.*, 2019). This understanding is vital to

changing attitudes and behaviour and facilitating adaptation and mitigation strategies for climate change.

Moreover, awareness-creation facilitates informed decision-making, which builds on adaptation and mitigation capabilities and encourages women and men to adopt more sustainable lifestyles. Climate change awareness creation is, thus, imperative to realise sustainability. Moreover, lack of awareness is a serious hurdle to climate change adaptation (Donkor *et al.*, 2017), especially for those measures with implications for the health of individuals. Awareness-raising is, therefore, an essential component of the adaptation process to manage the impacts of climate change, enhance adaptive capacity and reduce overall vulnerability. Awareness-raising revolves around effective communication channels to realise the desired results (Donkor *et al.*, 2017). Four-fifths of the respondents consider social media the most effective means of communication, suggesting that social media helps inform the public about climate change.

The fact that television is regarded as the second most popular information tool attests to its value as a source of information. The role of religious groups in climate change awareness has been gaining currency (Ferguson and Tamburello, 2015; Bomberg and Hague, 2018). However, Q2 shows that much work is still needed to harness this group's potential, as faith groups received minor responses as avenues for climate education. The UN has acknowledged religious groups/communities as core partners in conserving the environment and promoting sustainable development. Across the globe, spiritual beliefs and religion underpin cultural values, politics and the overall socio-economy (Nkoana, 2019). Harnessing the influence of religious leaders is, hence, vital for behavioural change and facilitating sustainable development.

The survey findings from Q3 revealed that the significant health hazards from climate change are mainly associated with extreme weather. As discussed earlier, heatwaves have become synonymous with worsening air pollution and allergies. The majority (67.9%) of the respondents indicated that worsening air pollution and allergies are the primary health hazard they have experienced related to climate change. These findings are consistent with the existing research undertaken in different contexts, such as Asia, Africa and Europe, pointing out the correlation between climate change, air pollution and allergies (D'Amato and Akdis 2020; Singh and Mathur, 2021). In addition, about 66% of the respondents indicated that infectious diseases were a significant health hazard from climate change. This is explained in studies that highlight how climate change impacts pathogens' geographic and seasonal distribution by influencing their habitat, environment and competitors (Wu *et al.*, 2016). The increases in infectious diseases emanating from climate change are also associated with the hosts and vectors that transmit these diseases.

Water and food contamination was identified by 65% of the respondents as a further health hazard related to climate change. This recognition of climate change's effects on water and food contamination is consistent with the literature (Xia *et al.*, 2015) that shows the impacts of climate change on the water quality of different bodies. The reduction of water quality compromises the safety of water supplies, thus posing serious health problems to communities, especially in rural areas.

Injuries and fatalities have been reported by 18.6% of the respondents, while 1.4% said other health effects with 0.7%, indicating no health hazards related to climate change. Nevertheless, these findings may not accurately portray reality, as many examples show the high morbidities associated with injuries related to extreme climatic events. For example, Cyclone Idai ravaged Beira city in Botswana and left a trail of destruction that included many injuries and deaths.

The findings presented in Q4 show the most vulnerable populations to climate change-related public health hazards. The majority (88.6%) of the respondents indicated that the poor are the most affected by the health hazards of climate change. The finding is consistent with the existing literature that shows how impoverished populations are more vulnerable to these hazards (Crimmins, 2016; Woetzel *et al.*, 2020). The living conditions of people in extreme poverty can explain this; the precarious livelihoods often expose them to climate change impacts. For this reason, 59.3% of the respondents identified residents of slums and squatter settlements as being highly affected by the health hazards of climate change, which is attributable to the fact that they tend to live in marginal spaces that are susceptible to different health risks. For example, flood plains may expose them to different pathogens and vectors. Older adults are identified by 71.4% of the respondents as the next vulnerable group to climate change. Individuals with underlying health conditions follow the elderly, as highlighted by 64.3% of the respondents. Children come next, as confirmed by 49.3% of the respondents.

Thus, only 1.4% have pointed out that everyone is vulnerable to the public health hazards of climate change. Interestingly, only 0.7% indicated that people in the Global South are more susceptible to climate change-related risks. However, many studies have shown that Africa is the most exposed continent to climate change (Niang *et al.*, 2014) and Asia (Hijioka *et al.*, 2014).

From the findings presented in Q5, most respondents (80.7%) agreed that regulations or public health policies are the most effective measures to mitigate and adapt to climate change's health hazards. This finding is consistent with the literature, which indicates how regulations and policies can effectively curb certain practices. Nevertheless, there are instances where these policies and regulations are not adequately implemented and do not achieve the purpose they were drafted for. Next, 67.9% affirmed that early warning systems and post-hazard responses are proper measures. Again, these are extensively documented in the literature, showing how early warning systems may help communities prepare and take preventive measures.

Nevertheless, despite the usefulness of early warning systems, miscommunication or mistrust among the communities may prevent them from being effective. For instance, during Hurricane Katrina, many members of local communities resisted early warning and even opposed post-hazard responses on the presumption that the local authority was trying to displace them from their homes.

The merits of green infrastructure, sea walls and levers were answered by 55.7% of the respondents, which shows their usefulness as tools for reducing property losses because of extreme weather.

Community resilience and connectedness were answered by 60.7% of the respondents as having the potential to reduce the health hazards of climate change, followed by 37.1%, who highlighted that health communication and outreach programs are effective tools in the process. Apart from the availability of health communication, there is a need for more medical care and vaccination, which was pointed out by 17.1% of the respondents.

5. Conclusions and recommendations

This paper presents an analysis of health responses to climate hazards and presents the results of a world study on the topic. The evidence collected allows some conclusions to be made. First and foremost, the literature review suggests the association between health hazards with extreme events, followed by climate change, particularly increased temperatures, and precipitation patterns, which is in close agreement with the IPCC findings. Regarding the primary climate-related diseases, cardiovascular, respiratory, water-

borne and food-borne prevail over other illnesses. Notwithstanding that only one-third of the papers researched both issues, we found evidence of a correlation between potential climate-health hazards. Noteworthy, only a few studies focused on Africa, which could be related to the origin of the authors, mainly from Europe, North America, Asia and Australia/New Zealand.

In addition, the responses to the questionnaire survey highlighted the following trends:

- the major climate-induced health problems – according to the sample – are heat distress and breathing difficulties;
- most respondents considered "Social media", followed by "Television" and the internet as the most effective tools for climate-raising awareness, well above the "Government agencies;
- most of the respondents mentioned worsening air pollution, infectious diseases, water and food contamination and cardiovascular and respiratory diseases as significant climate-related health hazards;
- the poor and older people were the most vulnerable groups to health hazards of climate change;
- emissions' regulations and policies ranked as the first measure to manage climate-related health hazards, followed by early warning and post-hazard responses and community resilience and connectedness.

This paper has some limitations. The first one is that the study relied on the term co-occurrence analysis provided by VOSviewer. Even though this is a frequently used bibliometric analysis technique, it has a constraint regarding the number of terms reliably assessed. Second, the survey entailed a sample of 140 respondents. This cannot be regarded as fully comprehensive but counts on a broad country representation.

Despite these limitations, the paper makes a timely contribution to the state of knowledge. It provides a profile of the literature on health responses to climate hazards and reports on a survey with delegates from 55 countries.

Based on the findings, public health responses to health hazards associated with climate change can be optimised by taking the following actions:

- Inclusion of climate-related health aspects in public health policies, particularly health promotion.
- Set up monitoring systems specific to health hazards to allow them to be identified promptly, which is vital in allowing more swift responses. Unfortunately, the lack of such systems is historically associated with the significant damages to property and losses of lives during extreme events such as floods, particularly those seen over the past years. If proper monitoring systems are in place, then there are good chances that the impacts of health hazards may be reduced.
- Adjustments in the critical infrastructure need to be made to prepare better to cope with extreme events and the potential health hazards associated with them. This includes shelter provisions during cyclones, typhoons and heatwaves and improvements in water storage facilities that can be more promptly deployed during dry periods.
- Specific plans to cope with heat and heatwaves, whose frequency and intensity in recent times negatively influence the liveability of many cities and regions.

- Specific initiatives to protect the most vulnerable groups in society, especially the poor and the elderly, pregnant women and young children.
- Continuous education and awareness-raising initiatives to better inform and mobilise the public for taking appropriate actions to reduce their vulnerability to health hazards.

Furthermore, as most developing countries have a high vulnerability and a low resilience capacity, it is necessary to consider specific support to help them cope with health hazards associated with climate change and extreme events as part of development aid. Here, international donors should consider adjusting their support lines to reflect the health impacts of climate change better. This may be instrumental in allowing vulnerable developing countries to obtain the resources needed to build resilience plans and, by doing so, be in a better position to handle the climate-related health hazards they are exposed to and, furthermore, to implement the measures needed to address them.

References

Akhtar, R. (2020), "Extreme weather events and human health", *International Case Studies*, Berlin Heidelberg: Springer Verlag, doi: 10.1007/978-3-030-23773-8.

Allen, M., Babiker, M., Chen, Y., Coninck, H., de, Connors, S., Diemen, R., van, Dube OP, Engelbrecht, F. Ferrat, M. *et al.* (2018), Summary for Policymakers Global Warming of 1.5°C.An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, available at: www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf, (accessed June 25 2020).

Andrady, A., Aucamp, P.J., Austin, A.T., Bais, A.F., Ballare, C.L., Barnes, P.W., Bernhard, G.H., Bjoern, L.O., Bornman, J.F., Congdon, N. and Cory, R.M. (2017), "Environmental effects of ozone depletion and its interactions with climate change, Progress report, 2016", *Photochem Photobiol Sci*, Vol. 16, pp. 107-145, doi: 10.1039/c7pp90001e.

Austin, S.E., Ford, J.D., Berrang-Ford, L., Biesbroek, R. and Ross, N.A. (2019), "Enabling local public health adaptation to climate change", *Social Science and Medicine*, Vol. 220, pp. 236-244.

Awuor, L., Meldrum, R. and Liberda, E.N. (2020), "Institutional engagement practices as barriers to public health capacity in climate change policy discourse: lessons from the Canadian province of Ontario", *International Journal of Environmental Research and Public Health*, Vol. 17 No. 17, p. 6338, doi: 10.3390/ijerph17176338.

Barrett, B., Charles, J.W. and Temte, J.L. (2015), "Climate change, human health, and epidemiological transition", *Preventive Medicine*, Vol. 70, pp. 69-75, doi: 10.1016/j.ypmed.2014.11.013.

Bell, J.E., Herring, SC, Jantarasami, L., Adrianopoli, C., Benedict, K., Conlon, K., Escobar, V., Hess, J., Luvall, J., Perez Garcia-Pando, C., Quattrochi, D., Runkle, J. and Schreck, III CJ. Ch. 4. (2016), "Impacts of extreme events on human health", in Crimmins, A., Balbus, J., Gamble, J.L., Beard, C.B., Bell, J.E., Dodgen, D., Eisen, R.J., Fann, N., Hawkins, M.D., Herring, S.C., Jantarasami, L., Mills, D.M., Saha, S., Sarofim, M.C., Trtanj, J. and Ziska, L. (Eds), *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, U.S. Global Change Research Program, Washington, DC, pp. 99-128, doi: 10.7930/J0BZ63ZV.

Bell, J.E., Langford Brown, C., Conlon, K., Herring, S., Kunkel, K.E., Lawrimore, J., Luber, G., Schreck, C., Smith, A. and Uejo, C. (2018), "Changes in extreme events and the potential impacts on human health", *Journal of the Air and Waste Management Association*, Vol. 68 No. 4, pp. 265-287, doi: 10.1080/10962247.2017.1401017.

Bomberg, E. and Hague, A. (2018), "Faith-based climate action in Christian congregations: mobilisation and spiritual resources", *Local Environment*, Vol. 23 No. 5, pp. 582-596, doi: 10.1080/13549839.2018.1449822.

Brubacher, J., Allen, D.M., Déry, S.J., Parkes, M.W., Chhetri, B., Mak, S., Sobie, S. and Takaro, T.K. (2020), "Associations of five Food-And Water-Borne diseases with ecological zone, land use and aquifer type in a changing climate", *Science of the Total Environment*, Vol. 728, p. 138808.

Byrd, B., Richards, S.L., Runkle, J.D. and Sugg, M.M. (2020), "Vector-borne diseases and climate change: North Carolina's policy should promote regional resilience", *N C Med J*, Vol. 81 No. 5, pp. 324-330.

Campbell-Lendrum, D., Wheeler, N., Maiero, M., Villa-Lobos Prats, E. and Neville, T. (2018), "COP24 special report. Health and climate change", World Health Organization, available at: https://apps.who.int/iris/bitstream/handle/10665/276405/9789241514972-eng.pdf?ua=1, (accessed 12 April 2021).

Centers for Disease Control and Prevention (2021), "Climate effects on health", available at: www.cdc.gov/climateandhealth/effects/default.htm (accessed 2 August 2021).

Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., Friel, S., Groce, N., Johnson, A., Kett, M., *et al.* (2009), "Managing the health effects of climate change", *The Lancet*, Vol. 373 No. 9676, pp. 1693-1733, doi: 10.1016/S0140-6736(09)60935-1.

Crimmins, A., Balbus, J., Gamble, J.L., Beard, C.B., Bell, J.E., Dodgen, D., Eisen, R.J., Fann, N., Hawkins, M.D., Herring, S.C., Jantarasami, L., Mills, D.M., Saha, S., Sarofim, M.C., Trtanj, J. and Ziska, L. (2016), "Impacts of climate change on human health in the United States: a scientific assessment", *U.S. Global Change Research Program*, Washington, DC, doi: 10.7930/J0R49NQX.

Cruz, J., White, P. and Bell, A. (2020), "Effect of extreme weather events on mental health: a narrative synthesis and meta-analysis for the U.K", *International Journal of Environmental Research and Public Health*, Vol. 17 No. 22, p. 8581, doi: 10.3390/ijerph17228581.

Curtis, S., Fair, A., Wistow, J., Val, D.V. and Oven, K. (2017), "Impact of extreme weather events and climate change for health and social care systems", *Environmental Health*, Vol. 16 No. S1, p. 128, doi: 10.1186/s12940-017-0324-3.

D'Amato, G. and Akdis, C.A. (2020), "Global warming, climate change, air pollution and allergies", *Allergy*, Vol. 75 No. 9, pp. 2158-2160, doi: 10.1111/all.14527.

De Sario, M., Katsouyanni, K. and Michelozzi, P. (2013), "Climate change, extreme weather events, air pollution and respiratory health in Europe", *European Respiratory Journal*, Vol. 42 No. 3, pp. 826-843, doi: 10.1183/09031936.00074712.

Demain, J.G. (2018), "Climate change and the impact on respiratory and allergic disease", Curr Allergy Asthma Rep, Vol. 18, No 4, pp. 1-5.

Donkor, F.K., Howarth, C., Ebhuoma, E., Daly, M., Vaughan, C., Pretorius, L., Mambo, J., MacLeod, D., Kythreotis, A., Jones, L., Grainger, S., Golding, N. and Anderson, J.A. (2019), "Climate services for development: the role of early career researchers in advancing the debate", EnvironCommun, Vol. 13, No 5, pp. 561-566, doi: 10.1080/17524032.2019.1596145.

Donkor, F.K., Tantoh, H. and Ebhuoma, E. (2017), "Social learning as a vehicle for catalysing youth involvement in sustainable environmental management CODESRIA bulletin number 3. Ecologies", *Economies and Societies in Africa*.

Ebi, K. and Bowen, K. (2016), "Extreme events as sources of health vulnerability: drought as an example", *Weather and Climate Extremes*, Vol. 11, pp. 95-102, doi: 10.1016/j.wace.2015.10.001.

Ebi, K.L., Mills, D.M., Smith, J.B. and Grambsch, A. (2006), "Climate change and human health impacts in the United States: an update on the results of the US National assessment", *Environmental Health Perspectives*, Vol. 114 No. 9, pp. 1318-1324, doi: 10.1289/ehp.8880.

Falagas, M.E., Bliziotis, I.A., Kosmidis, J. and Daikos, G.K. (2010), "Unusual climatic conditions and infectious diseases: observations made by Hippocrates", *Enfermedades Infecciosas y Microbiología Clínica*, Vol. 28 No. 10, pp. 716-718, doi: 10.1016/j.eimc.2009.11.013.

Ferguson, T. and Tamburello, J. (2015), "The natural environment as a spiritual resource: a theory of regional variation in religious adherence", *Sociology of Religion*, Vol. 76 No. 3, pp. 295-314, doi: 10.1093/socrel/srv029.

Fernández-Niño, J.A., Flórez-García, V.A., Astudillo-García, C.I. and Rodríguez-Villamizar, L. (2018), "A weather and suicide: a decade analysis in the five largest capital cities of Colombia", *International Journal of Environmental Research and Public Health*, Vol. 15 No. 7, p. 1313.

Gilbert, D.J. and Dako-Gyeke, M. (2018), "Lack of mental health career interest among Ghanaian social work students: implications for social work education in Ghana", *Social Work Education*, Vol. 37 No. 5, pp. 665-676.

Giorgini, P., di Giosia, P., Petrarca, M., Lattanzio, F., Stamerra, C.A. and Ferri, C. (2017), "Climate changes and human health: a review of the effect of environmental stressors on cardiovascular diseases across epidemiology and biological mechanisms", *Curr Pharm Des*, Vol. 23, p. 22, doi: 10.2174/1381612823666170317143248.

Greenough, G., McGeehin, M., Bernard, S.M., Trtanj, J., Riad, J. and Engelberg, D. (2001), "The potential impacts of climate variability and change on health impacts of extreme weather events in the United States", *Environ Health Perspect*, Vol. 109 No. 2, pp. 191-198, doi: 10.1289/ehp.109-1240666.

Guo Y., Gasparrini A. and Armstrong BG. (2017), "Heat wave and mortality: a multicountry, multicommunity study", *Environ. Health Perspect*, Vol. 125 No 8, pp. 1-11, doi:10.1289/EHP1026.2017,30:79-96.

Hajat, S., Kovats, R.S. and Lachowycz, K. (2007), "Heat-related and cold-related deaths in England and Wales: who is at risk?", *Occupational and Environmental Medicine*, Vol. 64 No. 2, pp. 93-100.

Hales S., Edwards S.J., Kovats R.S. (2003), "Impacts on health of climate extremes", in McMichael, A.J., Campbell-Lendrum, D.H., Corvalán, C.F., Ebi, K.L., Githeko, A.K., Scheraga, J.D. and Woodward A., (Eds), *Climate Change and Human Health: Risks and Responses*, World Health Organization, Geneva, pp. 79-102.

Hashim, J. and Hashim, Z. (2016), "Climate change, extreme weather events, and human health implications in the Asia pacific region", *Asia Pacific Journal of Public Health*, Vol. 28 No. 2, pp. 8S-14S, doi: 10.2307/26686238.

Head, B.W. (2014), "Evidence, uncertainty, and wicked problems in climate change decision making in Australia", *Environment and Planning C: Government and Policy*, Vol. 32 No. 4, doi: 10.1068/c124066379.

Herring, S.C., Christidis, N., Hoell, A., Kossin, J.P., Schreck, I.C. and Stott, P.A. (2018), "Explaining extreme events of 2016 from a climate perspective", *Bulletin of the American Meteorological Society*, Vol. 99 No. 1, pp. S1-S157.

Hijioka, Y., Lin, E., Pereira, J.J., Corlett, R.T., Cui, X., Insarov, G.E., Lasco, R.D., Lindgren, E., Surjan, A. Asia. in Barros, V.R., Field, C.B., Dokken, D.J., Mastrandrea, M.D., Mach, K.J., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R. and White, L.L. (Eds) (2014), "Climate change 2014: impacts", *Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, pp. 1327-70.

Hoegh-Guldberg, O., Taylor, J.D., Bolaños, M., Bindi, T.G., Brown, M., Camilloni, S., Diedhiou, I.A., Djalante, A. and Ebi, R. (2019), "The human imperative of stabilising global climate change at 1.5 C", *Science*, Vol. 365 No. 6459, p. 1263.

Huang, C., Barnett, A.G., Xu, Z., Chu, C., Wang, X., Turner, L.R. and Tong, S. (2013), "Managing the health effects of temperature in response to climate change: challenges ahead", *Environ Health Perspect*, Vol. 121, p. 4, doi: 10.1289/ehp.1206025.

Intergovernmental Panel on Climate Change (IPCC) (2021), "Climate change 2021: the physical science basis" *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, [Masson-Delmotte, V.P., Zhai, A., Pirani, S.L., Connors, C., Péan, S., Berger, N., Caud, Y., Chen, L., Goldfarb, M.I., Gomis, M., Huang, K., Leitzell, E., Lonnoy, J.B.R., Matthews, T.K., Maycock, T., Waterfield, O., Yelekçi, R., Yu. and B. Zhou (eds)], Cambridge University Press.

Javadinejad, S., Dara, R. and Jafary, F. (2020), "Health impacts of extreme events", *Safety in Extreme Environments*, Vol. 2 No. 2, pp. 171-181, doi: 10.1007/s42797-020-00016-8.

Kuehn, L. and Mccormick, S. (2017), "Heat exposure and maternal health in the face of climate change", *International Journal of Environmental Research and Public Health*, Vol. 14, No 8, p. 853, doi: 10.3390/ijerph14080853.

Leal Filho, W., Scheday, S., Boenecke, J., Gogoi, A., Maharaj, A. and Korovou, S. (2019), "Climate change, health and Mosquito-Borne diseases: trends and implications to the pacific region", *International Journal of Environmental Research and Public Health*, Vol. 16 No. 24, p. 5114, doi: 10.3390/ijerph16245114.

Leal Filho, W. (Eds) (2021), *Encyclopedia of the U.N. Sustainable Development Goals*, Springer, Cham.

Lemonsu, A., Viguié, V., Daniel, M. and Masson, V. (2015), "Vulnerability to heat waves: impact of urban expansion scenarios on urban heat island and heat stress in Paris France", *Urban Clim*, doi: 10.1016/j.uclim.2015.10.007.

McMichael, A.J., Campbell-Lendrum, D.H., Corvalán, C.F., Ebi KL, Githeko, A.K., Scheraga J.d. and Woodward, A. (2003), "Climate change and human Health-Risks and responses", *World HealthOrganization*, available at: www.who.int/globalchange/publications/cchhbook/en/, (accessed 18 May 2021).

Mason, L.R., Sharma, B.B., Walters, J.E. (2020), "Mental health and weather extremes in a south-eastern US city: exploring group differences by race, *International Journal of Environmental Research and Public Health*, Vol. 17 No. 10, p. 3411, doi: 10.3390/ijerph17103411.

Myers, T., Nisbet, M.C., Maibach, E.W. and Leiserowitz, A.A. (2012), "Public health frame arouses hopeful emotions about climate change", *Climatic Change*, Vol. 113 Nos 3/4, pp. 1105-1112, doi: 10.1007/s10584-012-0513-6.

Niang, I., Ruppel, O.C., Abdrabo, M.A., Essel A., Lennard, C., Padgham, J., Urquhart, P., Africa., Barros V.R., Field C.B., Dokken D.J., Mastrandrea M.D., Mach K.J., Bilir T.E., Chatterjee M., Ebi KL, Estrada Y.O., Genova RC, Girma B., Kissel E.S., Levy A.N., MacCracken S, Mastrandrea PR, White LL (Eds) (2014), "Climate change 2014: Impacts", *Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, p. 1199-265.

Nkoana, E.M. (2019), "Exploring the effects of an environmental education course on the awareness and perceptions of climate change risks among seventh and eighth-grade learners in South Africa", *International Research in Geographical and Environmental Education*, Vol. 29 No. 1, pp. 7-22, doi: 10.1080/10382046.2019.1661126.

Omisore, A.G. (2018), "Attaining sustainable development goals in Sub-Saharan Africa; the need to address environmental challenges", *Environmental Development*, Vol. 25, pp. 138-145.

Orru, H., Ebi, K.L. and Forsberg, B. (2017), "The interplay of climate change and air pollution on health", *Current Environmental Health Reports*, Vol. 4 No. 4, pp. 504-513, doi: 10.1007/s40572-017-0168-6.

Oven, K.J., Curtis, S.E., Reaney, S., Riva, M., Stewart, M.G., Ohlemüller, R., Dunn, C.E., Nodwell, S., Dominelli, L. and Holden, R. (2012), "Climate change and health and social care: defining future hazard, vulnerability and risk for infrastructure systems supporting older people's health care in England", *Applied Geography*, Vol. 33, pp. 16-24, doi: 10.1016/j.apgeog.2011.05.012.

Pachauri, R.K., Allen, M.R., Barros, V.R., Broome, J., Cramer, W., Christ, R., Church, J.A., Clarke, L., Dahe, Q., Dasgupta, P. and Dubash, N.K. (2014), "Climate change 2014: synthesis report contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change", *Intergovernmental Panel on Climate Change*, available at: www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf, (accessed 9 April 2021).

Palinkas, L.A. and Wong, M. (2020), "Global climate change and mental health", *Current Opinion in Psychology*, Vol. 32, pp. 12-16.

Parks, R.M., Bennett, J.E., Tamura-Wicks, H., Kontis, V., Toumi, R., Danaei, G. and Ezzati, M. (2020), "Anomalously warm temperatures are associated with increased injury deaths", *Nature Medicine*, Vol. 26 No. 1, pp. 65-70.

Patz, J.A., Gibbs, H.K., Foley, J.A., Rogers, J.V. and Smith, K.R. (2007), "Climate change and global health: quantifying a growing ethical crisis", *EcoHealth*, Vol. 4 No. 4, pp. 397-405.

Poursafa, P., Keikha, M. and Kelishadi, R. (2015), "Systematic review on adverse birth outcomes of climate change", *Journal of Research in Medical Sciences*, Vol. 20 No. 8, pp. 4-397.

Ray, C. and Ming, X. (2020), "Climate change and human health: a review of allergies, autoimmunity and the microbiome", *International Journal of Environmental Research and Public Health*, Vol. 17 No. 13, p. 4814, doi: 10.3390/ijerph17134814.

Reid, C.E., Brauer, M. and Johnston, F.H. (2016), "Critical review of health impacts of wildfire smoke exposure", *Environmental Health Perspectives*, Vol. 124 No. 9, pp. 1334-1343, doi: 10.1289/ehp.1409277.

Rocklöv, J. and Dubrow, R. (2020), "Climate change: an enduring challenge for vector-borne disease prevention and control", *Nature Immunology*, Vol. 21 No. 5, pp. 479-483.

Rossiello, M.R. and Szema, A. (2019), "Health effects of climate change-induced wildfires and heatwaves", *Cureus*, Vol. 11 No. 5, p. e4771, doi: 10.7759/cureus.4771.

Salata, F. Golasi, I. Petitti, D.L. Vollaro, E. de Coppi, M. de, L. and Vollaro, A. (2017), "Relating microclimate, human thermal comfort and health during heat waves: an analysis of heat island mitigation strategies through a case study in an urban outdoor environment", Sustain Cities Soc.

Schultz, L., Folke, C., Österblom, H. and Olsson, P. (2015), "Adaptive governance, ecosystem management, and natural capital", *Proceedings of the National Academy of Sciences*, Vol. 112 No. 24, pp. 7369-7374, doi: 10.1073/pnas.1406493112.

Seneviratne, S.I., Nicholls, N., Easterling, D., Goodess, C.M., Kanae, S, Kossin, J. and Reichstein, M. (2017), "Changes in climate extremes and their impacts on the natural physical environment", in Field, C.B., Barros, V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K. J, Plattner, G.-K., Allen, S.K., Tignor, M. and Midgley, P.M. (Eds), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, and New York, NY, pp. 109-230.

Singh, A.B. and Mathur, C. (2021), "Climate change and pollen allergy in India and South Asia", *Immunology and Allergy Clinics of North America*, Vol. 41 No. 1, pp. 33-52.

Smith, K., Woodward, A., Campbell-Lendrum, D., Chadee, D.D., Honda, Y., Liu, Q., Olwoch, J.M., Revich, B. and Sauerborn, R. (2014), "Human health: impacts, adaptation, and co-benefits", In Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S. Mastrandrea P.R. and White L.L. (Eds), *Climate Change 2014: impacts, Adaptation, and Vulnerability. Part A: global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, pp. 709-754.

Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M. (Eds), (2013), Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change",

Report of the Intergovernmental Panel on Climate Change Cambridge, Cambridge University Press Cambridge, United Kingdom and New York, NY, doi: 10.1017/CBO9781107415324.

Swinburn, B.A., Kraak, V.I., Allender, S., Atkins, V.J., Baker, P.I., Bogard, J.R. and Ezzati, M. (2019), "The global syndemic of obesity, undernutrition, and climate change: the lancet commission report", *The Lancet*, Vol. 393 No. 10173, pp. 791-846.

Tawatsupa, B., Yiengprugsawan, V., Kjellstrom, T., Seubsman, S.A. and Sleigh, A. (2012), "The Thai cohort study team heat stress, health and well-being: findings from a large national cohort of Thai adults", *BMJ Open*, Vol. 2 No. 6, p. e001396, doi: 10.1136/bmjopen-2012-001396.

Tong, S. and Ebi, K. (2019), "Preventing and mitigating health risks of climate change", *Environmental Research*, Vol. 174, pp. 9-13.

Van Woezik, A.F.G., Braakman-Jansen, L.M.A., Kulyk, O., Siemons, L. and Van Gemert-Pijnen, J.E.W.C. (2016), "Tackling wicked problems in infection prevention and control: a guideline for co-creation with stakeholders", *Antimicrobial Resistance and Infection Control*, Vol. 5 No. 1, p. 20, doi: 10.1186/s13756-016-0119-2.

Wang, H. and Horton, R. (2015), "Tackling climate change: the greatest opportunity for global health", *The Lancet*, Vol. 386 No. 10006, pp. 1798-1799, doi: 10.1016/s0140-6736(15)60931-x.

Watts, N., Adger, W.N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W., Chaytor, S., Colbourn, T., Collins, M., Cooper, A. and Cox, P.M. (2015), "Health and climate change: policy responses to protect public health", *The Lancet*, Vol. 386 No. 10006, pp. 1861-1914, doi: 10.1016/S0140-6736(15)60854-6.

Watts, N., Amann, M., Arnel, N., Ayeb-Karlsson, S., Belesova, K. and Boykof, M. (2019), "The 2019 report of the lancet countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate", *The Lancet*, Vol. 394 No. 10211, pp. 1836-1878, doi: 10.1016/S0140-6736(19)32596-6.

Watts, N., Amann, M., Arnell, N., Ayeb-Karlsson, S., Belesova, K., Berry, H. and Campbell-Lendrum, D. (2018), "The 2018 report of the lancet countdown on health and climate change: shaping the health of nations for centuries to come", *The Lancet*, Vol. 392 No. 10163, pp. 2479-2514.

WHO. Ambient air pollution: A global assessment of exposure and burden of disease (2016), "World health organization; WHO IRIS", available at: https://apps.who.int/iris/handle/10665/250141

WHO. Climate change and health. World Health Organization Key Facts (2018), available at: www.who.int/news-room/fact-sheets/detail/climate-change-and-health, (accessed 1 March).

Wistow, J., Dominell, L., Oven, K.J., Dunn, C.E. and Curtis, S.E. (2015), "The role of formal and informal networks in supporting older people's care during extreme weather events", *Policy and Politics*, Vol. 43 No. 1, pp. 119-135, doi: 10.1332/030557312X655855.

Woetzel, J., Pinner, D., Samandari, H., Engel, H., Krishnan, M., Boland, B. and Powis, C. (2020), Climate risk and response: physical hazards and socioeconomic impacts Report, McKinsey Global Institute, available at: www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts, (accessed 9 June 2021).

Woodcock, J., Edwards, P., Tonne, C., Armstrong, B.G., Ashiru, O., Banister, D., Beevers, S., Chalabi, Z., Chowdhury, Z., Cohen, A., Franco, O.H., Haines, A., Hickma, R., Lindsay, G., Mittal, I., Mohan, D., Tiwari, G., Woodward, A. and Roberts, I. (2009), "Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport", *The Lancet*, Vol. 374 No. 9705, pp. 1930-1943, doi: 10.1016/S0140-6736(09) 61714-1.

Wu, X., Lu, Y., Zhou, S., Chen, L. and Xu, B. (2016), "Impact of climate change on human infectious disease: empirical evidence and human adaptation", *Environment International*, Vol. 86, pp. 14-23.

Xia, X.H., Wu, Q., Mou, X.L. and Lai, Y.J. (2015), "Potential impacts of climate change on the water quality of different water bodies", *J Environ Inform*, Vol. 25 No. 2.

Yang, L., Liu, C., Bi, P., Vardoulakis, S. and Huang, C. (2020), "Local actions to health risks of heatwaves and dengue fever under climate change: strategies and barriers among primary healthcare professionals in Southern China", *Environmental Research*, Vol. 187, p. 109688.

Author affiliations

Walter Leal Filho, Department of Natural Sciences, Manchester Metropolitan University, Manchester, UK and Research and Transfer Centre "Sustainable Development and Climate Change Management (FTZ-NK), Faculty of Life Sciences, Hamburg University of Applied Sciences, Hamburg, Germany

Linda Ternova, Research and Transfer Centre "Sustainable Development and Climate Change Management" (FTZ-NK), Faculty of Life Sciences, Hamburg University of Applied Sciences, Hamburg, Germany

Muhammad Muddassir Fayyaz, Department of Health Sciences, Faculty of Life Sciences, Hamburg University of Applied Sciences, Hamburg, Germany

Ismaila Rimi Abubakar, College of Architecture and Planning, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia

Marina Kovaleva, Hochschule fur Angewandte Wissenschaften Hamburg, Hamburg, Germany

Felix Kwabena Donkor, University of South Africa, Pretoria, South Africa

Samuel Weniga Anuga, Climate Change and Sustainable Development Programme, University of Ghana College of Health Sciences, Accra, Ghana

Abraham R. Matamanda, Department of Geography, University of the Free State, Bloemfontein, South Africa

Ilija Djekic, Department of Food Safety and Quality Management, Faculty of Agriculture, University of Belgrade, Beograd, Serbia

Ibrahim Abatcha Umar, Department of Research and Planning, Kwara State University, Malete, Nigeria

Felicia Motunrayo Olooto, Department of Agricultural Economics and Extension Services, Faculty of Agriculture, Kwara State University, Malete, Nigeria

Maria Meirelles, Department of Physics Sciences, Chemistry and Engineering, Faculty of Science and Technology, University of the Azores, Ponta Delgada, Portugal

Gustavo J. Nagy, Department of Ecología y Ciencias Ambientales, Facultad de Ciencias, Universidad de la República, Montevideo, Uruguay

Julia May, Department of Health Sciences, Faculty of Life Sciences, Hamburg University of Applied Sciences, Hamburg, Germany

Marta May, Faculty of Life Sciences, Hamburg University of Applied Sciences, Hamburg, Germany

Eromose Ebhuoma, Department of Environmental Sciences, University of South Africa-Florida Campus, Florida, South Africa

Halima Begum, School of Economics, Finance and Banking (SEFB), Universiti Utara Malaysia, Sintok, Malaysia

About the authors

Walter Leal Filho holds the Chairs of Climate Change Management at the Hamburg University of Applied Sciences (Germany) and Environment and Technology at Manchester Metropolitan University (the UK). He directs the Research and Transfer Centre "Sustainability Development and Climate Change Management". His main research interests are sustainable development and climate change, including aspects of climate change and health.

Linda Ternova is a Master in Public Health candidate at the Hamburg University of Applied Sciences, Germany. She has a Master degree in Pharmacy. Her research focuses on environmental health policies, environmental health, climate change and zoonoses.

Muhammad Muddassir Fayyaz is a Master in Public Health candidate at Hamburg University of Applied Sciences, Germany. His research areas focus on current challenges related to environmental health and climate change.

Ismaila Rimi Abubakar is a Professor of urban sustainability. He earned a PhD in Urban and Regional Planning from Florida State University, a Master in City and Regional Plan from KFUPM and an MSc in Computing from Robert Gordon University, the UK. He has published over 60 articles and book chapters in high-impact journals and edited volumes in urban sustainability, climate change, sustainable urbanisation and basic urban services. He has been awarded four research grants. He is an Associate Editor of the *International Journal of Climate Change Strategies and Management* and a fellow of the Population Reference Bureau, Washington DC, and many organisations. Ismaila Rimi Abubakar has a PhD (FSU, the USA), M.CRP (KFUPM, Saudi Arabia), MSc (RGU, the UK) and B.URP (ABU, Nigeria). Abubakar is listed among the world's top 2% scientists by Stanford University and is a Professor of Urban Sustainability, College of Architecture and Planning, IAU, Dammam, KSA.

Marina Kovaleva is a PhD Candidate at the Hamburg University of Applied Sciences, Germany. Her research focuses on the gender dimension within the climate change context.

Felix Kwabena Donkor is a Postdoctoral fellow at the College of Agriculture and Environmental Sciences (CAES) of the University of South Africa (UNISA). He is the President of the African Students and Alumni Forum (ASAF) and the immediate past Vice-chair for the South African Adaptation Network; a steering committee member of Future Earth's Knowledge-Action Network (KAN) on sustainable consumption and production as well its RISK KAN; a coordinator for the Young Scholars Initiative (YSI) and the Early Careers Network. Being passionate about education, he also serves as a country representative mentor for the Erasmus Mundus Students and Alumni Association (EMA). His research interests include the sustainable food–water–energy nexus, indigenous knowledge systems, resilience, education and sustainable development. His hobbies include cycling, swimming, jogging, writing and music.

Samuel Weniga Anuga is at the Institute for Environment and Sanitation Studies (IESS), University of Ghana. His research focuses on International Climate Policy and Environmental Health.

Abraham R. Matamanda is a Lecturer in the Department of Geography, Faculty of Natural and Agricultural Sciences, Bloemfontein Campus, University of the Free State. Abraham holds a PhD in Urban and Regional Planning from the University of the Free State in South Africa. He also has a BSc (Hons) in Rural and Urban Planning and an MSc in Social Ecology, both obtained from the University of Zimbabwe. Matamanda's research focuses on informal urbanism, human settlement planning, urban political ecology and economy, climate change adaptation and medical geography. Matamanda has published widely on issues related to urban planning. His recent publications include a book he co-edited titled "Urban Geography in Postcolonial Zimbabwe: Paradigms and perspectives for sustainable urban planning and governance", published by Springer Nature (2021).

Ilija Djekic is a Full Professor at the Faculty of Agriculture, University of Belgrade. He holds an engineering PhD in life-cycle assessment joint with over 25 years of experience in the food sector. His teaching and research areas cover various dimensions of food sustainability. He supervised over 75 PhD, master's and bachelor's theses. Djekic has (co-) authored more than 250 full papers, 10 chapters and 5 books, of which (120+) in international journals from Food Science and Technology and Environmental areas included in the © ISI Web of Knowledge. In addition, he serves as an Editor in different peer-reviewed journals covering food sustainability and environmental science. His service to science covers peer-reviewing for highly ranked scientific journals (100+reviews), reviewing scientific project proposals for the European Commission (Horizon Europe and COST actions) and for national scientific bodies (Poland, Kazakhstan).

Ibrahim Abatcha Umar is a First-Class Graduate of Geography from the University of Maiduguri and is currently a postgraduate research student at Ibadan, Nigeria. He presently works with Borno State University as teaching staff in the Department of Geography. His research interest includes Climate Change, application of GIS and Remote Sensing, urban studies, and water and food security.

Felicia Motunrayo Olooto is a Lecturer in the Agricultural Economics and Extension Services Department at Kwara State University Malete, Nigeria. She obtained a BSc Agricultural Extension Services from the University of Ibadan, Nigeria. She also got her MSc and PhD degrees in Agricultural Extension and Rural Development from the University of Ibadan, Nigeria. She teaches Agricultural Extension and Rural Sociology courses at undergraduate and postgraduate levels. She is a member of learned professional associations such as the Agricultural Extension Society of Nigeria

(AESON), Rural Sociological Association of Nigeria (RuSAN) and Nigeria Forum of Agricultural Advisory Services (NIFAAS). Her areas of Research Interest are Rural/Community Development, Climate Smart Agriculture, Gender Studies and Women in Development.

Maria Meirelles is a PhD in Physics, area of specialisation in Geophysical Sciences, since 2009. Meirelles is a Professor at the University of the Azores since 1992, in the Department of Sciences of Physics, Chemistry and Engineering. Over the years, she has taught several subjects to students from different courses, supervised internships and theses and participated in the continuous training of teachers. At the same time, she has been developing research work, publishing several articles in specialist journals and book chapters and participating in several national and international research projects. Also, she has participated in the organisation of scientific congresses and in several events to disseminate science. Her research areas are climate change and health and climate change and environmental sustainability.

Gustavo J. Nagy is an Associate Professor of Environmental Sciences at the University of the Republic, Montevideo, Uruguay (Udelar). He earned a PhD in Oceanography from the University of Bordeaux I, France. Professor Nagy taught/teaches at the Udelar (Uruguay), Polytechnic School, Asunción, Paraguay, and WASCAL Climate Change Education Programme, The Gambia, West Africa, supervises MSC and PhD Thesis in Uruguay, Venezuela and Germany. He was a Lead Author of the IPCC AR-4 and AR-6 WG II. He is Deputy/Associate Editor of three international journals and reviewer of 37 journals. His main research interests are climate adaptation, sustainable development goals and interdisciplinary climate studies. Gustavo J. Nagy is the corresponding author and can be contacted at: gnagy@fcien.edu.uy

Julia May is currently studying Health Sciences at the Hamburg University of Applied Sciences. May has worked as a student assistant at the Research and Transfer Centre "Sustainable Development and Climate Change Management" (FTZ-NK), Hamburg University of Applied Sciences (HAW).

Marta May has worked as a Research Assistant at the Research and Transfer Centre "Sustainable Development and Climate Change Management" at the Hamburg University of Applied Sciences, Germany. She is currently pursuing a bachelor's degree in Health Sciences at the Hamburg University of Applied Sciences.

Eromose Ebhuoma is a Postdoctoral researcher in the Department of Environmental Sciences, College of Agriculture and Environmental Sciences, University of South Africa (UNISA). His research expertise spans climate change vulnerability and adaptation, climate services, climate policy and governance, local and indigenous knowledge systems, political ecology and rural livelihoods in sub-Saharan Africa. Currently, he is a South African Adaptation Network steering committee member under the climate policy portfolio.

Halima Begum is an Assistant Professor of the Finance Department in the School of Economics, Finance and Banking (SEFB), Universiti Utara Malaysia (Best Eminent Management University, AMBA and AACSB-accredited business school). She is an Associate Editor in IJCCS-Emerald, Topic Editor in Frontiers in Environmental Science and Frontiers in Sustainability, Editorial in Research and Innovation Initiative and Editorial in Frontiers Psychology. Begum is an "Associate Fellow" for the CSRC (Pakistan-Malaysia-Lebanon Collaborative RI). She did her PhD in environmental management at the National University of Malaysia. She has expertise in sustainable development, including sustainable and techno-finance, Islamic finance and environmental economics.