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Rhéa Rocque, Caroline Beaudoin, Ruth Ndjaboue, Laura Cameron ...+5 more authors

Institutions: University of Winnipeg, Laval University, University of Toronto

Published on: 30 Sep 2020 - medRxiv (Cold Spring Harbor Laboratory Press)

Topics: Effects of global warming, Systematic review, Social determinants of health and Climate change

The Health Effects of Climate Change: An Overview of Systematic Reviews

Rhéa Rocque, PhD[1], Caroline Beaudoin, DEC[2], Ruth Ndjaboue, MPH, PhD [2,3], Laura Cameron, MA[1], Louann Poirier Bergeron, DES[2], Rose-Alice Poulin-Rheault, DEC[2], Catherine Fallon, MSc[2,4], Andrea C. Tricco, PhD [5,6], Holly O. Witteman, PhD[2,3,4]

[1]Prairie Climate Centre, University of Winnipeg, Winnipeg
[2]Faculty of Medicine, Laval University, Quebec City
[3]VITAM Research Centre for Sustainable Health, Quebec City
[4]Research Centre of the CHU de Québec-Laval University, Quebec City
[5]Li Ka Shing Knowledge Institute, Unity Health Toronto, Toronto
[6]Dalla Lana School of Public Health, University of Toronto, Toronto

Corresponding author:
Rhéa Rocque – rhea.rocque@gmail.com

Abstract

Background: Although many studies have explored the health impacts of climate change, a broader overview of research is needed to guide future research and action to mitigate and adapt to the health impacts of climate change.

Methods: We conducted an overview of systematic reviews of health impacts of climate change. We systematically searched the literature using a predefined search strategy, inclusion, and exclusion criteria. We included systematic reviews that explored at least one health impact of climate change. We organized systematic reviews according to their key characteristics, including geographical regions, year of publication and authors' affiliations. We mapped the climate effects and health outcomes being studied and synthesized major findings.

Findings: We included ninety-four systematic reviews. Most were published after 2015 and approximately one fifth contained meta-analyses. Reviews synthesized evidence about five categories of climate impacts; the two most common were meteorological and extreme weather events. Reviews covered ten health outcome categories; the three most common were 1) infectious diseases, 2) mortality, and 3) respiratory, cardiovascular, cardiopulmonary or neurological outcomes. Most reviews suggested a deleterious impact of climate change on multiple adverse health outcomes, although the majority also called for more research.

Interpretation: Overall, most systematic reviews suggest that climate change is associated with worse human health. Future research could explore the potential explanations between these associations to propose adaptation and mitigation strategies and could include psychological and broader social health impacts of climate change.

Funding: Canadian Institutes of Health Research FDN-148426

Introduction

The environmental consequences of climate change such as rising temperatures, more extreme weather events, and increased droughts and flooding are impacting human health and lives.[1,2] Previous studies and reviews have documented the health impacts of climate change; however, they have focused on specific climate effects,[3,4] health impacts,[5,6] countries,[7–9] or are no longer up to date.[10,11] To guide future research and action to mitigate and adapt to the health impacts of climate change and its environmental consequences, we need a complete and thorough overview of the research already conducted. In this study, we aimed to develop such a synthesis of systematic reviews of health impacts of climate change. Our research objectives were to synthesize studies' characteristics such as geographical regions, years of publication, and authors' affiliations, to map the climate impacts, health outcomes, and combinations of these that have been studied, and to synthesize key findings.

Methods

We applied the Cochrane method for overviews of reviews.[12] This method is designed to systematically map the themes of studies on a topic and synthesize findings to achieve a broader overview of the available literature on the topic.

Research questions

Our research questions were the following: 1) What is known about the relationship between climate change and health, as shown in previous systematic reviews? 2) What are the characteristics of these studies? We registered our plan (CRD42019145972[13]) in PROSPERO, an international prospective register of systematic reviews and followed PRISMA 2020[14] to report our findings, as a reporting guideline for overviews is still in development.[15]

Search strategy and selection criteria

To identify relevant studies, we used a systematic search strategy. We included studies in this review if they 1) were systematic reviews of original research and 2) reported at least one health impact as it related (directly or indirectly) to climate change.

We defined a systematic review, based on Cochrane's definition, as a review of the literature in which one "attempts to identify, appraise and synthesize all the empirical evidence that meets pre-specified eligibility criteria to answer a specific research question [by] us[ing] explicit, systematic methods that are selected with a view aimed at minimizing bias, to produce more reliable findings to inform decision making."[16] We included systematic reviews of original research, with or without meta-analyses. We excluded narrative reviews, non-systematic literature reviews and systematic reviews of materials that were not original research (e.g., systematic reviews of guidelines.)

We based our definition of health impacts on the World Health Organization's (WHO) definition of health as, "a state of complete physical, mental and social well-being and not merely the

absence of disease or infirmity."[17] Therefore, health impacts included, among others, morbidity, mortality, new conditions, worsening/improving conditions, injuries, and psychological well-being. Climate change (or global warming) could be referred to directly or indirectly, for instance, by synthesizing the direct or indirect health effects of temperature rises or of natural conditions/disasters made more likely by climate change (e.g., floods, wildfires, temperature variability, droughts.) We included systematic reviews whose main focus was not the health impacts of climate change, providing they reported at least one result regarding health effects related to climate change (or consequences of climate change.)

On June 22, 2019, we retrieved systematic reviews regarding the health effects of climate change by searching the electronic databases Medline, CINAHL, Embase, Cochrane, Web of Science using a structured search (see Appendix 1 for final search strategy developed by a librarian.) We did not apply language restrictions. After removing duplicates, we imported references into Covidence.[18]

Screening process

To select studies, we first screened titles and abstracts to eliminate articles that did not meet our inclusion criteria. Two trained analysts independently screened each article. A senior analyst resolved any conflict or disagreement. Because the topic was new to some team members, to ensure a high-quality screening process, the trained analysts then re-screened all included records and the senior analyst re-screened all excluded records. Two analysts then independently screened the full text of retained articles, again with a senior analyst resolving disagreements.

Data extraction

Next, we decided on key information that needed to be extracted from studies. We extracted the first author's name, year of publication, number of studies included, time frame (in years) of the studies included in the article, first author's institution's country affiliation, whether the systematic review included a meta-analysis, geographical focus, population focus, the climate impact(s) and the health outcome(s) as well as the main findings and limitations of each systematic review.

Two or more trained analysts (RR, CB, RN, LC, LPB, RAPR) independently extracted data, using Covidence and spreadsheet software (Google Sheets). For analysts who were new to evidence syntheses (CB, LPB, RAPR), the training process included extracting data repeatedly from the same articles to ensure accurate understanding, weekly group meetings to clarify understanding, and daily supervision by more senior team members (RR, RN, HOW). An additional trained analyst from the group or senior research team member resolved disagreements between individual judgments.

Coding and Data Mapping

To summarize findings from previous reviews, we used a three-step procedure for coding and data mapping. First, to map articles according to climate impacts and health outcomes, two

researchers (RR and LC) consulted the titles and abstracts of each article. We developed the categories for climate impacts separately from those for health outcomes and used a mixed approach to coding. We started with an inductive coding method, by identifying categories directly based on our data and followed up with a deductive approach to finalize categories by consulting previous conceptual frameworks of climate impacts and health outcomes.[1,2,19] The same two researchers independently coded each article according to their climate impact and health outcome. We then compared coding and resolved disagreements through discussion.

Next, still using spreadsheet software, we created a matrix to map articles according to their combination of climate impacts and health outcomes. Each health outcome occupied one row, whereas climate impacts each occupied one column. We placed each article in the matrix according to the combination(s) of their climate impact(s) and health outcome(s). For instance, if we coded an article as 'extreme weather' for climate and 'mental health' for health impact, we noted it in the cell at the intersection of these two codes. We calculated frequencies for each cell to identify frequent combinations and gaps in literature. Because one study could investigate more than one climate impact and health outcome, the frequency counts for each category could exceed the number of studies included in this review.

Finally, we summarized findings of the studies individually according to their combination of climate impacts and health outcomes. We re-read the Results and Discussion sections of each article as part of this step. We first wrote an individual summary for each study, then we collated the summaries of all studies exploring the same combination of categories to develop an overall summary of findings for each combination of categories.

Quality assessment

We used a modified version of AMSTAR-2 to assess the quality of the included systematic reviews (Appendix 2). Since AMSTAR-2 was developed for syntheses of systematic reviews of randomized controlled trials, working with a team member with expertise in knowledge synthesis (AT), we adapted it to suit a research context that is not amenable to randomized controlled trials. We used items 5, 6, 10, 11, 12, 14, 15, 16 without modification and modified items 1 to 4, 7 to 9 and 13.

Results

Articles identified

As shown in the PRISMA diagram in Figure 1, from an initial set of 2619 references, we retained 94 for inclusion.

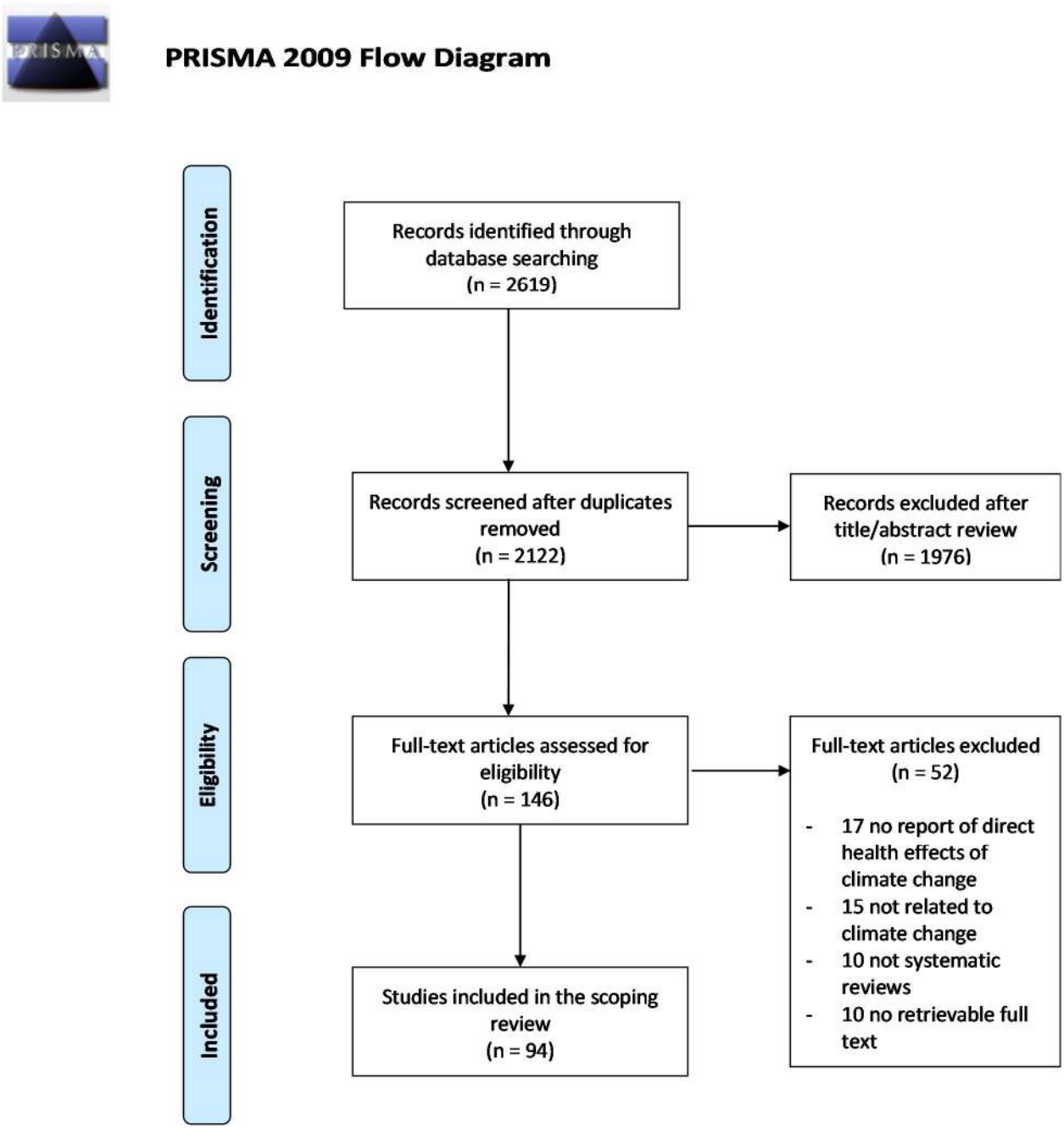

Figure 1. The flow chart for included articles in this review.

Study Descriptions

A detailed table of all articles and their characteristics can be found in Appendix 3. Publication years ranged from 2007 to 2019 (year of data extraction), with the great majority of included articles (n = 69; 73%) published since 2015 (Figure 2). A median of 30 studies had been included in the systematic reviews (mean = 60; SD = 49; range 7 to 722). Approximately one fifth of the systematic reviews included meta-analyses of their included studies (n = 18; 19%). The majority of included systematic reviews' first authors had affiliations in high-income

countries, with the largest representations by continent in Europe (n = 30) and Australia (n = 24) (Figure 3).

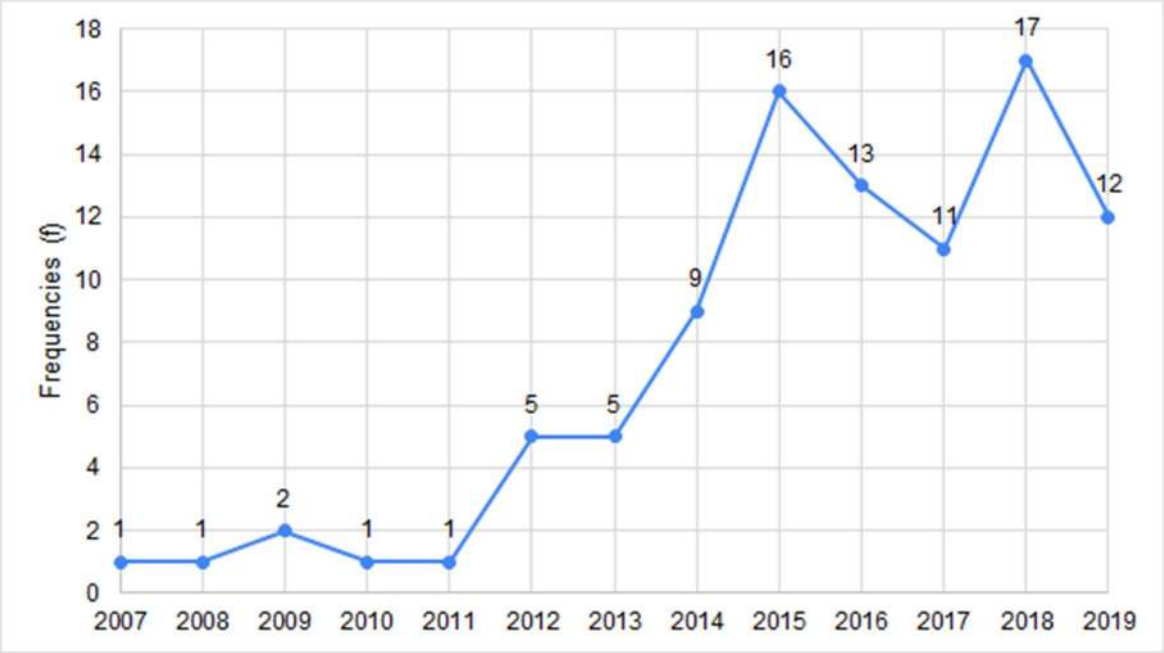

Figure 2. Number of included systematic reviews by year of publication.

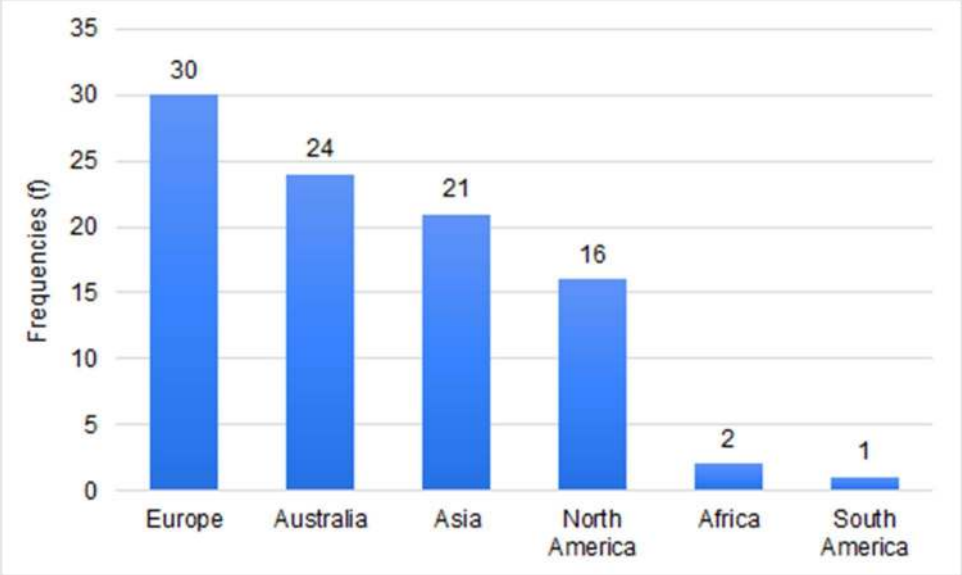

Figure 3. Number of publications according to geographic affiliation of the first author.
*Countries of origin within continents in frequency order (highest to lowest frequency) and alphabetical: ***Europe***: United-Kingdom (9), Germany (6), Italy (4), Sweden (4), Denmark (2), France (2), Georgia (1), Greece (1) and Finland (1). ***Australia****:* All Australia. ***Asia****:* China (11), Iran (4), India (1), Jordan (1), Korea (1), Nepal (1), Philippines (1), Taiwan (1). ***North America:*** United-States (15), Canada (1). ***Africa:*** Ethiopia (1), Ghana (1). ***South America:*** Brazil (1).

Regarding the geographical focus of systematic reviews, most of the included studies (n = 68; 72%) had a global focus or no specified geographical limitations and therefore included studies published anywhere in the world. The remaining systematic reviews either targeted certain countries (n = 12) (1 for each Australia, Germany, Iran, India, Ethiopia, Malaysia, Nepal, New Zealand and 2 reviews focused on China and the United States), continents (n = 5) (3 focused on Europe and 2 on Asia), or regions according to geographical location (n = 6) (1 focused on Sub-Saharan Africa, 1 on Eastern Mediterranean countries, 1 on Tropical countries, and 3 focused on the Arctic), or according to the country's level of income (n = 3) (2 on low to middle income countries, 1 on high income countries).

Regarding specific populations of interest, most of the systematic reviews did not define a specific population of interest (n = 69; 73%). For the studies that specified a population of interest (n = 25; 26.6%), the most frequent populations were children (n = 7) and workers (n = 6), followed by vulnerable or susceptible populations more generally (n = 4), the elderly (n = 3), pregnant people (n = 2), people with disabilities or chronic illnesses (n = 2) and rural populations (n = 1).

Quality assessment

We assessed studies for quality according to our revised AMSTAR-2. Out of 94 systematic reviews, the most commonly fully satisfied criterion was #1 (PICO components) with 81/94 (86%) of included systematic reviews fully satisfying this criterion. The next most commonly-satisfied criteria were #16 (potential sources of conflict of interest reported) (78/94 = 83% fully), #13 (account for limitations in individual studies) (70/94 = 75% fully and 2/94 = 2% partially), #7 (explain both inclusion and exclusion criteria) (64/94 = 68% fully and 19/94 = 20% partially), #8 (description of included studies in adequate detail) (36/94 = 38% fully and 41/94 = 44% partially), and #4 (use of a comprehensive literature search strategy) (0/94 = 0% fully and 80/94 = 85% partially). For criteria #11, #12, and #15, which only applied to reviews including meta-analyses, 17/18 (94%) fully satisfied criterion #11 (use of an appropriate methods for statistical combination of results), 12/18 (67%) fully satisfied criterion #12 (assessment of the potential impact of RoB in individual studies) (1/18 = 6% partially), and 11/18 (61%) fully satisfied criterion #15 (an adequate investigation of publication bias, small study bias). Full details are available in Appendix 4.

Climate Impacts and Health Outcomes

For both the climate impacts and health outcomes, systematic reviews could have a general or a specific focus. A general focus consisted of investigating the general impacts of climate change or multiple impacts simultaneously, whereas a specific focus targeted specifically only one climate impact or health outcome. When combining the climate impact to the health outcome, four combinations became apparent. Table 1 shows these four combinations with sample titles of systematic reviews within that combination. The most frequent combination (n = 52; 55%) consisted of studies investigating a specific climate impact on a specific health outcome (e.g., the impact of floods on mental health) and the least frequent combination (n = 5;

5%) consisted of studies exploring general or multiple climate impacts' effects on multiple health outcomes (e.g., health impacts of climate change.)

Table 1. Summary of the four scenarios possible when combining climate impact and health outcome categories with frequencies and examples of paper titles.

Frequency (%) and Example Titles		**Health Outcome**	
		Multiple (n = 29)	Specific (n = 65)
Climate Impact	General or multiple (n = 18)	n = 5 (5%) E.g., "Health Impact of Climate Change in Older People: An Integrative Review and Implications for Nursing,"[20] and, "Climate Change and Health in the Eastern Mediterranean Countries: A Systematic Review."[21]	n = 13 (14%) E.g., "Global Warming and Obesity,"[22] and, "Systematic Review of Current Efforts to Quantify the Impacts of Climate Change on Undernutrition."[23]
	Specific (n = 76)	n = 24 (26%) E.g., "Floods and Human Health: A Systematic Review,"[3] and, "Health Effects of Drought: A Systematic Review of the Evidence."[24]	n = 52 (55%) E.g., "The Mental Health Outcomes of Drought: A Systematic Review and Causal Process Diagram,"[25] and, "The Association between Ambient Temperature and Childhood Asthma: A Systematic Review."[26]

Regarding climate impacts, we identified five mutually exclusive categories, with 13 publications targeting more than one category of climate impacts: 1) Meteorological (n = 71 papers) (e.g., temperature, heat waves, humidity, precipitation), 2) Extreme weather (n = 24) (e.g., water-related, floods, cyclones, hurricanes, drought), 3) Air quality (n = 7) (e.g., air pollution and wildfire smoke exposure), 4) General (n = 5), and 5) Other (n = 3). "General" climate impacts included articles that did not specify climate change impacts but stated general climate change as their focus. "Other" climate impacts included studies investigating other effects indirectly related to climate change (e.g., impact of environmental contaminants) or general environmental risk factors (e.g., environmental hazards, sanitation, and access to clean water.)

We identified ten categories to describe the health outcomes studied by the systematic reviews, and 29 publications targeted more than one category of health outcomes: 1) Infectious diseases (n = 41 papers) (vector-, food- and water-borne), 2) Mortality (n = 32), 3) Respiratory, cardiovascular, cardiopulmonary and neurological (n = 22), 4) Healthcare systems (n = 16) , 5) Mental health (n = 13), 6) Pregnancy and birth (n = 11), 7) Dietary (n = 9), 8) Skin and allergies (n = 9), 9) Occupational health and injuries (n = 6) and 10) Other health outcomes (n = 17) (e.g., sleep, arthritis, disability-adjusted life years, non-occupational injuries, etc.)

Figure 4 depicts the combinations of climate impact and health outcome for each study, with Appendix 5 offering further details. The 5 most common combinations are studies investigating the 1) meteorological impacts on infectious diseases (n = 35), 2) mortality (n = 24) and 3) respiratory, cardiovascular, cardiopulmonary and neurological outcomes (n = 17), and 4) extreme weather events' impacts on infectious diseases (n = 14) and 5) meteorological impacts on health systems (n = 11).

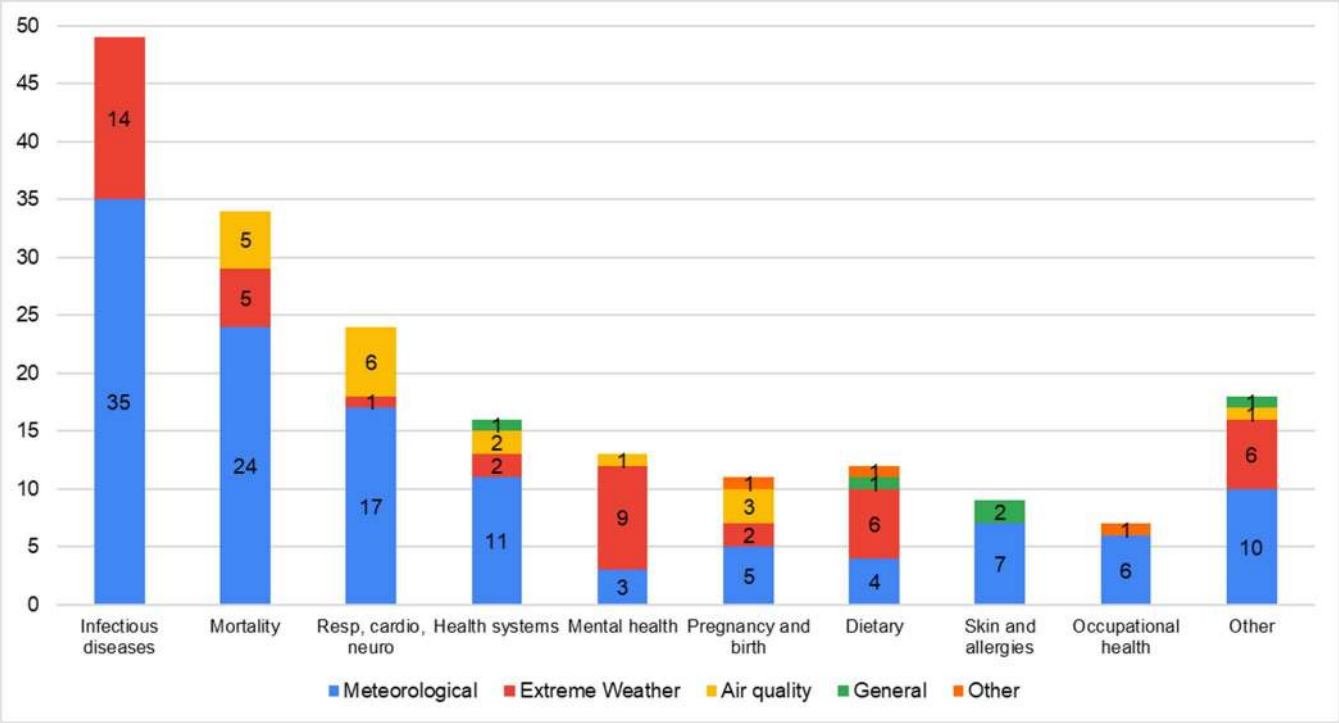

Figure 4. Summary of the combination of climate impact and health outcome (frequencies). *Note:* The total frequency for one category of health outcome could exceed the number of publications included in this health outcome, since one publication could explore the health impact according to more than one climate factor (e.g., one publication could explore both the impact of extreme weather events and temperature on mental health.)

For studies investigating meteorological impacts on health, the three most common health outcomes studied were impacts on 1) infectious diseases (n = 35), 2) mortality (n = 24) and 3) respiratory, cardiovascular, cardiopulmonary and neurological outcomes (n = 17). Extreme weather event studies most commonly reported health outcomes related to 1) infectious diseases (n = 14), 2) mental health outcomes (n = 9) and 3) dietary outcomes (n = 6) and other health outcomes (e.g., injuries, sleep) (n = 6). Studies focused on the impact of air quality were less frequent and explored mostly health outcomes linked to 1) respiratory, cardiovascular, cardiopulmonary and neurological outcomes (n = 6), 2) mortality (n = 5) and 3) pregnancy and birth outcomes (n = 3).

Meteorological factors' impact on all health outcomes are explored, although some health outcomes are more rarely explored (e.g., mental health and dietary outcomes). In contrast, the impact of extreme weather events and air quality on skin and allergies and occupational health are not explored and their impacts on respiratory, cardiovascular, cardiopulmonary and neurological outcomes, health systems and pregnancy outcomes are only rarely explored. The impacts of air quality on infectious diseases, dietary outcomes, skin and allergies, and occupational health and injuries are also not explored. Most health outcomes are most frequently explored according to the meteorological impacts, however, mental health outcomes and dietary outcomes are most frequently explored according to extreme weather events.

Summary of Findings

Most reviews suggest a deleterious impact of climate change on multiple adverse health outcomes, with some associations being explored and/or supported with consistent findings more often than others (see Table 2 for a summary of findings according to health outcomes). For instance, the association between meteorological factors, such as temperature and humidity, and vector-borne diseases is quite substantially supported by multiple reviews (n = 22) conducted in multiple geographic locations. In contrast, the association between wildfire smoke exposure and adverse birth outcomes is plausible, but the evidence from included reviews is still in its infancy stage because only a few reviews (n = 3) investigated this association and the findings are currently conflicting.

Most reviews concluded by calling for more research, noting the limitations observed among the studies included in their reviews, as well as limitations in their reviews themselves. These limitations included, amongst others, some systematic reviews having a small number of publications,[27,28] language restrictions such as including only papers in English,[20,23] arriving at conflicting evidence,[29] difficulty concluding a strong association due to the heterogeneity in methods and measurements or the limited equipment and access to quality data in certain contexts,[27,30–32] and most studies included were conducted in high-income countries.[33,34]

Previous authors also discussed the important challenge related to exploring the relationship between climate change and health. Not only is it difficult to explore the potential causal relationship between climate change and health, mostly due to methodological challenges, but there are also a wide variety of complex causal factors that may interact to determine health outcomes. Therefore, the possible causal mechanisms underlying these associations were at times still unknown or uncertain and the impacts of some climate factors were different according to geographical location and specificities of the context. Nonetheless, some reviews offered potential explanations for the climate-health association, with the climate factor at times, having a direct impact on health (e.g., flooding causing injuries) and in other cases, having an indirect impact (e.g., flooding causing stress which in turn may cause adverse birth outcomes.)

Table 2. Summary of findings from systematic reviews according to health outcome and climate impact. Reviews that covered multiple climate impacts are listed in each relevant category.

Climate Impact	F	Summary of Findings
Infectious diseases (n = 41)		
Vector borne infectious diseases (n = 25)		
Meteorological	22	Systematic reviews suggest that meteorological factors, such as temperature, precipitation, humidity, and wind, are associated with diverse vector-borne infectious diseases, including malaria and dengue.[6,9,20,21,30,32,35–50] This association was mostly proportional (e.g., higher temperature and increased rainfall associated with vector-borne diseases), although findings were at times conflicting, with some suggesting an inversely proportional association[9] (e.g., decreased rainfall) or no association at all[40] (e.g., with the human puumala hantavirus Infection.) Geographic location, seasonality and potential interaction with other climate-related factors may partly explain these inconsistencies.[9,30] Temperature, humidity and rainfall were the most common and important meteorological factors reported by reviews and factors such as wind, air pressure and sunshine were reported less often.
Extreme weather	7	There are limited and conflicting findings concerning the association of extreme weather events with vector-borne diseases. Some reviews suggest water-related extreme events[51] and flooding[3,32,52] are associated with an increased risk of vector-borne diseases, while drought is associated with a reduction of dengue incidence.[9] Other reviews focused specifically on Puerto Rico[43] and Australia[53] did not find an association between hurricanes and/or floods and mosquito-borne disease transmission.
Food and water borne infectious diseases (n = 19)		
Meteorological	14	Reviews suggest that meteorological factors, such as temperature, precipitation, and humidity, are associated with diverse food- and water-borne infectious diseases, in particular, cholera, food poisoning, schistosomiasis, salmonella and E. coli.[8,21,32,41,45,48,54–61] Overall, higher temperatures and humidity,[8,41,54,58] along with lower precipitation[21,61] was associated with these infectious diseases (e.g., E. coli[58]; bacterial gastrointestinal infections.[54]) Directionality and strength of the association seemed to vary according to disease and pathogens,[59] seasons, and geographic region.[56]
Extreme weather	10	Reviews suggest a proportional association between extreme water-related events,[47,51,62] such as flooding[3,41,52] and heavy rainfall[35], and food- and water-borne diseases, including diarrhea, food contamination, cholera.[3,32,35,41,45,47,51,52,57,62] Drought may also be proportionally associated with food- and water-borne disease,[24,35] but these associations are less consistent than those with water-related extreme events.[57]
Other infectious diseases (n = 8)		

Meteorological	8	Reviews suggest an association of most meteorological factors, such as temperature and humidity, with various other infectious diseases, including meningitis,[27,35] Ebola,[27] influenza, [32] and pediatric infectious diseases such as hand-foot-and-mouth disease.[4,5,31,49,55] This association was mostly proportional for meteorological factors such as temperature,[4,5,49] diurnal temperature range,[31] and humidity,[4,5,32] although some meteorological factors, such as air pressure[5] and lower temperatures[32,49] were inversely proportional to these diseases. Some conflicting evidence is reported concerning the association with some meteorological factors, such as sunshine with hand-foot-and-mouth disease,[4,5] and humidity and pediatric infectious diseases.[55] No association was found between some meteorological factors, such as precipitation, wind speed and sunshine with hand-foot-and-mouth disease.[4,5]
Mortality (n = 32)		
Meteorological	24	Reviews suggest that temperature (high, low, or diurnal range) was consistently associated with all-cause and cause-specific mortality.[20,21,27,28,31,34,45,47,49,63–76] A strong association was reported between heat (including heat waves) and mortality (all-cause),[63] heat-,[21,68] stroke-,[27,69] cardiovascular-,[34,47] and respiratory-related,[20,34,70] especially in rural,[67] very young children[49] and ageing populations.[28] Mortality seems to be the most frequent health outcome studied in association with heatwaves.[64] Inconsistent results are found concerning the association between heat and childhood mortality.[74] Due to limited evidence, this association was weaker in some geographical regions.[27,71] Also, heat wave intensity (compared to duration) was more strongly associated with heat-related mortality.[75] Finally, although less studied, low temperature was also associated with mortality,[49,76] specifically respiratory,[63] stroke,[69] and cardiovascular mortality.[47,66,70]
Extreme Weather	5	Reviews suggest an association between extreme weather events such as floods,[3] droughts,[24] cyclones[77] and other water-related events,[20,51] with direct (e.g., drowning) and indirect long-term mortality (e.g., due to malnutrition, environmental toxin exposure, armed conflict, etc.).[3,24,51,77]
Air quality	5	Reviews suggest an association between exposure to air pollution[20,78] or wildfire smoke[79–81] and air pollution related-mortality, such as respiratory-specific mortality. There is currently limited evidence, but reviews suggest a potential association between wildfire smoke exposure and cardiovascular-specific mortality.[79–81]
Respiratory, neurological, cardiovascular and cardiopulmonary (n = 22)		

Meteorological	17	Reviews suggest an association between meteorological factors, such as temperature and humidity, and cardiopulmonary, cardiovascular, respiratory and neurological outcomes.[20,26,27,31,34,37,45,49,55,63,66,68,69,73,74,82,83] Exposure to high temperatures and extreme heat are associated to cardiovascular and respiratory diseases,[20,27,37,49,66] stroke,[69] long-term neurological outcomes (due to heat strokes),[68] myocardial infarction,[34,83] and childhood asthma and pediatric respiratory diseases.[26,74] A review also suggests a beneficial association between heat and the shortening of a respiratory virus season.[45] Exposure to low temperature (cold), temperature drop, or diurnal temperature range was associated with cardiovascular and respiratory diseases,[31,63,66] stroke,[69] and myocardial infarctions.[34] Humidity (most often high humidity, but also lower humidity) and low temperatures were also associated with respiratory diseases in children, including childhood asthma.[26,55,82]
Extreme Weather	1	A previous review suggests an association between drought and respiratory, cardiovascular and cardiopulmonary outcomes, most likely due to droughts leading to increased dust in the air.[24]
Air quality	6	Reviews suggest a proportional association between exposure to air pollution[20,21,45] or wildfire smoke exposure[79–81] and respiratory outcomes, including asthma, chronic obstructive pulmonary disease, coughing, wheezing, and overall lung function. Although there is currently limited evidence,[79] reviews also suggest a potential association between air pollution or wildfire smoke exposure and cardiovascular outcomes.[45,80,81]
Health systems (n = 16)		
General	1	A previous review suggests that climate change in general puts a strain on public health resources, via population health issues and shows that using an integrated surveillance system may guide future adaptation to climate change.[84]
Meteorological	11	Previous reviews suggest an association between temperature change[31] extreme heat, aridity and cold temperatures and an increase in use of healthcare services (mostly linked to heat-related health impacts), such as an increase in emergency department visits, hospital admissions and use of ambulances.[20,21,27,31,34,49,64,71,74,83,85]
Extreme weather	2	Reviews suggest that extreme weather events[33] and flooding[3] are associated with an increase in use of healthcare services (e.g., increased hospitalizations) and a compromised quality of care as extreme weather events may lead to power outages.[33]
Air quality	2	Reviews suggest an association between wildfire smoke exposure and an increase in use of healthcare services, such as an increase in emergency department visits.[79,81]
Mental health (n = 13)		

Meteorological	3	Reviews suggest an association of most meteorological factors such as temperature increase, aridity, heat, and heat waves with mental health outcomes, including hospital admissions for mental health reasons,[21] suicide,[86] and exacerbation of pre-existing mental health conditions, difficulty sleeping, and fatigue.[83] No association was found between sunlight duration and suicide incidence.[86]
Extreme weather	9	Most reviews reported a proportional association of extreme weather events,[45,51,87,88] flooding,[3,20,89] and drought[24,25] with diverse mental health issues, including, psychological distress, post-traumatic stress disorder, anxiety, depression, psychotropic medication use, alcohol consumption. There was conflicting evidence regarding the association of floods with suicide, tobacco, alcohol and substance abuse.[89] No association was found between drought and suicide.[24]
Air quality	1	A previous review suggests no association between wildfire smoke exposure and mental health, as measured by physician visits and hospitalizations for mental health reasons during wildfires.[80]
Pregnancy and birth outcomes (n = 11)		
Meteorological	5	Reviews suggest that adverse birth outcomes are higher among people exposed to meteorological factors such as high temperature, heat, sunlight intensity, cold and humidity.[21,90–93] These outcomes include low birth weight, preterm birth, eclampsia and preeclampsia, hypertension and length of pregnancy.[21,90–93] The association between heat and adverse birth outcomes seems to have stronger support than the association with cold temperatures.[93]
Extreme Weather	2	Reviews suggest an association of extreme weather events[87] and flooding[3] with adverse birth outcomes, such as low birth weight, preterm birth and pre-eclampsia. It is suggested that extreme weather events may indirectly affect birth outcomes via the pregnant person's well-being (e.g., stress and worry during pregnancy.)[3,87]
Air quality	3	There is limited and inconsistent evidence concerning the association between wildfire smoke exposure and adverse birth outcomes, but reviews suggest a potential proportional association between wildfire smoke exposure and lower birth weight.[79–81]
Other	1	The association between environmental pollutants and adverse birth outcomes (i.e., preterm birth) remains unclear due to conflicting evidence.[29]
Dietary (n = 9)		
General	1	A review suggests an association between climate change and obesity.[22]
Meteorological	4	Reviews suggest an association between meteorological factors, such as changes in temperature, heat and precipitation, with diverse dietary outcomes, including undernutrition, malnutrition and child stunting.[21,23,27,71] This association may be

		explained by the impact of meteorological factors, such as temperature increase and precipitation decrease, on crop production and food insecurity.[21,71]
Extreme Weather	6	Reviews suggest an association between extreme weather events, such as flooding and droughts,[24] and diverse dietary outcomes, including malnutrition and undernutrition in children and adults[21,23,35,45,47] via, amongst others, crops production and food insecurity (e.g., low food aid following flooding[21]).
Other	1	A review suggests an association between certain environmental risk factors (e.g., sanitation, cooking fuels and food-borne mycotoxins), and childhood stunting, which could be aggravated by climate change.[94]
Skin and allergies (n = 9)		
General	2	Reviews suggest a proportional association between climate change, in general, and skin and soft tissue infections (e.g., fatal vibrio vulnificus necrotizing)[95] and ragweed pollen allergies in Europe.[96]
Meteorological	7	Reviews suggest an association of meteorological factors, such as ultraviolet light exposure, temperature and humidity, with diverse skin and allergic diseases, including skin cancer, sunburn, acute urticaria, eczema and pediatric allergies and skin irritabilities.[27,45,47,49,55,83,97] Higher temperature and ultraviolet light exposure is proportionally associated with sunburn[83] and skin cancer,[45,97] while low humidity and low temperatures were associated with eczema and skin irritabilities in children.[49,55]
Occupational health and injuries (n = 6)		
Meteorological	6	Reviews suggest that heat is associated with adverse occupational health outcomes, including injuries, heat strain, dehydration and kidney diseases.[98–103] The most frequent injuries consist of 'slips, trips, falls, wounds, lacerations and amputations.'[99] This association was found in many occupational settings, including agriculture, construction, transport and fishing, and seems to affect both outdoor and indoor workers.[98] This association may be explained by a combination of direct (e.g., dehydration) and indirect factors (e.g., impaired cognitive and physical performance.)[102]
Other	1	A review suggests an association between environmental pollution (e.g., heavy metals, fertilizers, etc.) and occupational diseases, such as chronic kidney disease.[103] This association is suggested to be affected by increasing temperatures.
Other (n = 17)		

General	1	A review suggests an association between climate change in general and disability-adjusted life years, which is an indicator that quantifies 'the burden of disease attributable to climate change'.[104] Authors suggest that the cost of disability-adjusted life years could be high, especially in low to middle income countries.
Meteorological	10	Reviews suggests an association between increasing temperatures and temperature changes,[31] and other various health outcomes, including acute gouty arthritis,[105] unintentional injuries,[106] diabetes,[63] genitourinary diseases,[31,63] impaired sleep time and quality,[107] cataracts (indirectly associated via people spending more time outside and therefore increased exposure to ultraviolet light),[45,47] heat stress, heat exhaustion and kidney failure,[83] and renal diseases, fever and electrolyte imbalance in children.[49,74]
Extreme weather	6	Reviews suggests an association between extreme weather events,[88] such as flooding,[3] cyclones,[77] hurricanes,[107] and drought,[24] and other various health outcomes including injuries (e.g., debris, diving in water that is shallower than expected),[3,24,77,88] impaired sleep,[107] esophageal cancer (likely linked to high salinity of water due to droughts),[24] and exacerbation of chronic illnesses.[3,87]
Air quality	1	There is limited evidence, but a systematic review suggests an association between wildfire smoke exposure and ophthalmic outcomes, such as eye irritation and cataracts.[79]

Discussion

Principal results

In this overview of systematic reviews, we aimed to develop an overview of systematic reviews of health impacts of climate change by mapping the characteristics and findings of studies exploring the relationship between climate change and health. We identified four key findings.

First, the most common climate impact studied by included publications consists of meteorological impacts (e.g., temperature, heat, precipitation and humidity), which aligns with findings from a previous scoping review on the health impacts of climate change in the Philippines.[7] Although this may not be surprising given that a key implication of climate change is the rise in temperature, this finding suggests we also need to undertake research focused on other climate impacts on health, such as the impact of droughts and wildfire smoke, to better prepare for the health crises that arise from these multiple climate-related impacts.

Second, systematic reviews primarily focus on physical health outcomes, such as infectious diseases, mortality, and respiratory, cardiopulmonary, cardiovascular and neurological outcomes, which also aligns with the country-specific previous scoping review.[7] Regarding mortality, we support Campbell and colleagues'[64] suggestion that we should expand our focus

to include other types of health outcomes. This will allow us to better mitigate and adapt to the full range of threats of climate change.

It is unclear whether the distribution of frequencies of health outcomes reflects the actual burden of health impacts of climate change, or if the most frequently reported outcomes reflect a bias of Western definitions of health. The most commonly-studied health outcomes do not necessarily reflect the definition of health presented by the WHO as, "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."[17] This suggests that future studies should investigate in greater depth the impacts of climate change on mental and broader social well-being. Indeed, some reviews suggested that climate change impacts psychological and social well-being, via broader consequences, such as political instability, health system capacity, migration, and crime,[83,87] thus illustrating how our personal health is determined not only by biological and environmental factors but also by social and health systems.

Interestingly, the reviews that explored the mental health impacts of climate change were focused mostly on the direct impacts of experiencing extreme weather events. However, psychologists are also warning about indirect mental health impacts of climate change, which are becoming more prevalent for children and adults alike.[108,109] Even people who do not experience direct climate impacts, such as extreme weather events, report experiencing disruptive negative emotions when thinking of the destruction of our environment or when worrying about one's uncertain future and the lack of actions being taken. To foster emotional resilience in the face of climate change, these mental health impacts of climate change need to be further explored. Humanity's ability to adapt to and mitigate climate change ultimately depends on our emotional capacity to face this threat.

Third, there is a notable geographic difference in the country affiliations of first authors, with three quarters of systematic reviews having been led by first authors affiliated to institutions in Europe, Australia, or North America. While perhaps unsurprising given the inequalities in research funding and institutions concentrated in Western countries, this is of critical importance given the significant health impacts that will be faced in other parts of the world. Research funding organizations should seek to provide more resources to authors in low- to middle-income countries to ensure their expertise and perspectives are better represented in the literature.

Fourth, overall, most reviews suggest an association between climate change and the deterioration of health in various ways, thus illustrating the interdependence of our health and well-being with the well-being of our environment. At times, climate change and its related environmental events may impact health directly (e.g., heat's impact on dehydration and exhaustion) and other times, it may impact it indirectly (e.g., via behaviour change due to heat.) The climate-health link has been the target of more research in recent years and it is also receiving increasing attention in both public health and climate communication literature.[110,111] The health framing of climate communication also has implications for healthcare professionals[112] and policymakers, as these actors could play a key part in climate

communication, adaptation, and mitigation. These key stakeholders' perspectives on the climate-health link, as well as their perceived role in climate adaptation and mitigation could be explored,[113] since research suggests that health professionals are important voices in climate communications[112] and especially since, ultimately, these adverse health outcomes will engender pressure on and cost to our health systems and health workers.

Strengths and Limitations

To the best of our knowledge, the current study provides the first broad overview of previous systematic reviews exploring the health impacts of climate change. Our review has three main strengths. First, by targeting systematic reviews, we achieve a higher-order summary of findings than what would have been possible by consulting individual original studies. Second, by synthesizing findings across all included studies and according to the combination of climate impact and health outcome, we offer a clear, detailed, and unique summary of the current state of evidence and knowledge gaps about how climate change may influence human health. This summary may be of use to researchers, policymakers, and communities. Third, we included studies published in all languages about any climate impact and any health outcome. In doing so, we provide a comprehensive and robust overview.

Our work has three main limitations. First, we were unable to access some full texts and therefore some studies were excluded, even though we deemed them potentially relevant after title and abstract inspection. Other potentially relevant systematic reviews may be missing due to unseen flaws in our systematic search. Second, due to the heterogeneity of the included systematic reviews and the relatively small proportion of studies reporting meta-analytic findings, we could not conduct meta-meta-analyses of findings across reviews. Future research is needed to quantify the climate and health links described in this review, as well as to investigate the causal relationship and other interacting factors. Third, due to limited resources, we did not assess overlap between the included reviews concerning the studies they included. Frequencies and findings should be interpreted with potential overlap in mind.

Conclusions

Overall, systematic reviews of the health impacts of climate change suggest an association between climate change and the deterioration of health in multiple ways, generally in the direction that climate change is associated with adverse human health outcomes. This is worrisome since these outcomes are predicted to rise in the near future, due to the temperature rise and increase in climate-change-related events such as extreme weather events and worsened air quality. Most studies included in this review focused on meteorological impacts of climate change on adverse physical health outcomes. Future studies could fill knowledge gaps by exploring other climate-related impacts and broader psychosocial health outcomes. Moreover, studies on health impacts of climate change have mostly been conducted by first authors affiliated with institutions in high-income countries. This inequity needs to be addressed, considering that the impacts of climate change are and will continue to predominantly impact lower-income countries. Finally, although most reviews also recommend more research to

better understand and quantify these associations, to adapt to and mitigate climate change's impacts on health, it will also be important to unpack the 'what, how, and where' of these effects. Health effects of climate change are unlikely to be distributed equally or randomly through populations. It will be important to mitigate the changing climate's potential to exacerbate health inequities.

Acknowledgements

The authors gratefully acknowledge the contributions of Selma Chipenda Dansokho, as research associate, and Thierry Provencher, as research assistant, to this project, and of Frederic Bergeron, for assistance with search strategy, screening and selection of articles for the systematic review.

Funding

This study was funded by the Canadian Institutes of Health Research (CIHR) FDN-148426. The CIHR had no role in determining the study design, the plans for data collection or analysis, the decision to publish, nor the preparation of this manuscript. ACT is funded by a Tier 2 Canada Research Chair in Knowledge Synthesis. HOW is funded by a Tier 2 Canada Research Chair in Human-Centred Digital Health.

Authors' Contributions

RN, CF, ACT, HOW contributed to the design of the study. CB, RN, LPB, RAPR and HOW contributed to the systematic search of the literature and selection of studies. RR, HOW, LC conducted data analysis and interpretation. RR and HOW drafted the first version of the article with early revision by CB, LC and RN. All authors critically revised the article and approved the final version for submission for publication. RR and HOW had full access to all the data in the study and had final responsibility for the decision to submit for publication.

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APPENDICES

Appendix 1. Search Strategy

Database: **MEDLINE (OVID)**
No database limit

Concepts	#	Search strategy
Global Warming	1	exp Climate Change/
	2	"Global warming".ti,ab,kw
	3	"Climate Change?".ti,ab,kw
Global Warming combined	4	or/1-3
Systematic review and meta-analysis	5	exp Meta-Analysis as Topic/
	6	"Meta-Analysis"/
	7	Meta-Analysis.ti,ab,kw
	8	"meta analy*".ti,ab,kw
	9	metaanaly*.ti,ab,kw
	10	"Systematic Review"/
	11	"Systematic Reviews as Topic"/
	12	(systematic adj2 review).ti,ab,kw
	13	(review adj1 ("selection criteria" OR "data extraction")).ti,ab
Systematic review and meta-analysis combined	14	or/5-13

Combination of concepts	15	4 AND 14

Database: **Embase.com**
No database limit

Concepts	**#**	**Search strategy**
Global Warming	1	'climate change'/de
	2	'greenhouse effect'/de
	3	"Global warming":ti,ab,kw
	4	"Climate Change*":ti,ab,kw
Global Warming combined	5	#1 OR #2 OR #3 OR #4
Systematic review and meta-analysis	6	'meta analysis'/exp
	7	'meta analysis (topic)'/de
	8	Meta-Analysis:ti,ab,kw
	9	"meta analy*":ti,ab,kw
	10	metaanaly*:ti,ab,kw
	11	'systematic review'/de
	12	(systematic NEAR/2 review):ti,ab,kw
	13	(review NEAR/2 ("selection criteria" OR "data extraction")):ti,ab

Systematic review and meta-analysis combined	14	#7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14
Combination of concepts	15	#14 AND #5
Embase database only	16	AND [embase]/lim NOT ([embase]/lim AND [medline]/lim)

Database: **Web of Science**
Limit to: Science Citation Index Expanded (SCI-EXPANDED) and Emerging Sources Citation Index (ESCI) index only

Concepts	**#**	**Search strategy**
Global Warming	1	TS=("Global warming" OR "Climate Change$")
Systematic review and meta-analysis	2	TS=(Meta-Analysis)
	3	TS=("meta analy*")
	4	TS=(metaanaly*)
	5	TS=(systematic NEAR/2 review)
	6	TS=(review NEAR/1 ("selection criteria" OR "data extraction"))
Systematic review and meta-analysis combined	7	#6 OR #5 OR #4 OR #3 OR #2
Combination of concepts	8	#7 AND #1

Database: **CINAHL**
No database limit

Concepts	**#**	**Search strategy**
Global Warming	1	MH "Climate Change"
	2	MH "Greenhouse Effect"
	3	TI "Global warming"
	4	TI "Climate Change?"
	5	AB "Global warming"
	6	AB "Climate Change?"
Global Warming combined	7	S1 OR S2 OR S3 OR S4 OR S5 OR S6
Systematic review and meta-analysis	8	MH "Meta Analysis"
	9	TI "Meta-Analysis"
	10	AB "Meta-Analysis"
	11	TI "meta analy*"
	12	AB "meta analy*"
	13	TI metaanaly*
	14	AB metaanaly*
	15	MH "Systematic Review"
	16	TI (systematic N2 review)
	17	AB (systematic N2 review)
	18	TI (review N1 ("selection criteria" OR "data extraction"))

	19	AB (review N1 ("selection criteria" OR "data extraction"))
Systematic review and meta-analysis combined	20	S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19
Combination of concepts	21	S7 AND S20

Appendix 2. Summary of AMSTAR-2 items and modified AMSTAR-2 items.

Item #	AMSTAR-2 Original Item	AMSTAR-2 Modifications
1	Did the research questions and inclusion criteria for the review include components of PICO? - Population - Intervention - Comparator group - Outcome - Timeframe for follow-up (optional)	"Population" became "Population and/or location". "Intervention" became "Exposure". The "Comparator group" category was taken out. A new section (#1.b)) was created, it includes "Definition of the exposure", "Definition of the outcome" and "Timeframe for follow up".
2	Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?	To score "yes", a protocol must have been established before the review. There are no sub-criterias, you can only score yes or no.
3	Did the review authors explain their selection of the study designs for inclusion in the review?	If the study designs are specified, you score "partial yes". They must be explained to score "yes". No specific study design is required.
4	Did the review authors use a comprehensive literature search strategy?	The "searched trial/study registries" category was taken out. Justified publication restrictions (e.g. language) moved from (partial yes) to (yes)
5	Did the review authors perform study selection in duplicate?	No modifications.
6	Did the review authors perform data extraction in duplicate?	No modifications.
7	Did the review authors provide a list of excluded studies and justify the exclusion?	The explanation of the inclusion and exclusion criteria is evaluated. If there is only one out of the two, you score "partial yes". The two must be explained to score "yes".
8	Did the review authors describe the included studies in adequate detail?	"Populations" became "Populations and/or locations". "Interventions" became "Exposures". "Comparator groups" became "Comparator groups (if applicable)". "Populations and/or locations", "Exposures" and "Outcomes" must be described in details to score "yes"
9	Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review?	"RoB" became "limitations". Instead of assessing the RoB, the review authors must have used a satisfactory technique for assessing the limitations in individual studies that were included in the review.

10	Did the review authors report on the sources of funding for the studies included in the review?	No modifications.
11	If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results?	No modifications.
12	If meta-analysis was performed, did the review authors assess the potential impact of RoBin individual studies on the results of the meta-analysis or other evidence synthesis	No modifications.
13	Did the review authors account for RoB in individual studies when interpreting/discussing the results of the review?	“RoB” became “limitations”. Instead of accounting for RoB in individual studies, the review authors must have accounted for limitations when interpreting/ discussing the results of the review.
14	Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?	No modifications.
15	If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?	No modifications.
16	Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?	No modifications.

Appendix 3. Overview of included studies (N=94) according to study characteristics and summary of climate impacts on health outcomes. Studies are presented in alphabetical order according to the first author's last name.

	First Author	Year	Country	Years of included publications	Years of the studies included in the reviews	# of articles	Meta-analysis	Specific Area of focus	Specific Population of interest	Climate Impact	Health Outcome	Summary of findings
1	Alderman	2012	Australia	2004-2011	1931-2007	35	No			Extreme weather	Infectious diseases Mortality Health systems Mental health Pregnancy and birth Other	Floods are associated with infectious diseases (water- and vector-borne diseases), mortality (e.g., drowning), exacerbation of chronic illnesses, mental health issues (e.g., PTSD), hospital admissions, pregnancy outcomes and injuries.
2	Amegah	2016	Ghana	1995-2014	1960-2010	23	No	Sub-saharan Africa		Meteorological	Infectious diseases Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes Health systems Dietary Skin and allergies	Temperature and temperature variability are suggested to be associated with infectious diseases, such as Ebola, cardiovascular diseases, mortality, cholera outbreaks, meningitis, undernutrition in children, respiratory outcomes, such as asthma, and skin diseases.
3	An	2018	United States	2002-2017	2002-2016	50	No			General	Dietary	Climate change is associated with obesity. This association can be explained in 4 ways, such that climate change may impact obesity, obesity may impact climate change, both factors may be associated with

												common causes, or both factors may influence each other.
4	Augustin	2008	Germany	1996-2006	NS	320	No	Germany		Meteorological	Skin and allergies	Although skin and allergic diseases are climate sensitive, there is not sufficient evidence to suggest a prediction concerning skin and allergic diseases linked to climate change in Germany.
5	Babaie	2018	Iran	2007-2017	1970-2015	14	No	Iran		Meteorological	Infectious diseases	Temperature, precipitation and humidity are associated with the risk of transmission of Malaria.
6	Bai	2013	China	1995-2011	1951-2010	57	No	China		Meteorological	Infectious diseases	Variability in temperature, precipitation and wind are associated with the risk of transmission of mosquito-borne diseases.
7	Benevolenza	2019	United States	2006-2017	2005-2015	13	No		Vulnerable populations	Extreme weather	Mental health Pregnancy and birth Other	Extreme weather events are associated with an exacerbation of pre-existing chronic health conditions, mental health issues (e.g., PTSD, isolation) and adverse birth outcomes.
8	Berhane	2016	Ethiopia	NS	NS	23	No	Ethiopia		Meteorological Extreme weather	Infectious diseases Dietary	Meteorological factors and extreme weather events are associated with under- and mal- nutrition and the increased risk of climate sensitive infectious diseases (e.g., malaria, diarrhea, zoonotic infections, etc.).
9	Bernhardt	2019	Germany	1997-2017	NS	464	No			Meteorological	Infectious diseases	Rising temperatures are predicted to be associated with myiasis in the future.
10	Binazzi	2019	Italy	NS	1994-2013	8	Yes		Workers	Meteorological	Occupational health and injuries	High temperatures are positively associated with occupational injuries.
11	Bonafede	2016	Italy	2000-2014	1985-2010	8	No		Workers	Meteorological	Occupational health and injuries	Extreme temperature (particularly heat) is associated with occupational injuries.
12	Brown	2013	United Kingdom	2004-2012	1975-2012	38	No	Europe		Extreme weather	Infectious diseases	Floods are associated with infectious diseases, including water-, rodent- and vector-borne diseases (from weeks to months after flooding).

13	Bunker	2016	Germany	1995-2015	1974-2013	61	Yes		Elderly	Meteorological	Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes Other	Higher and lower temperatures are associated with cardiovascular and respiratory morbidity and mortality. Heat is also associated with diabetes and genitourinary infections.
14	Campbell	2018	Australia	1964-2017	NS	188	No			Meteorological	Mortality Health systems	Most studies exploring the heat impacts on health focus on mortality outcomes, followed by hospital admissions and ambulance call outs.
15	Cann	2013	United Kingdom	1973-2010	NS	83	No			Extreme weather	Infectious diseases	Extreme water-related events are associated with outbreaks of water-related infectious diseases.
16	Carolan-Olah	2014	Australia	1997-2012	1988-2009	7	No			Meteorological	Pregnancy and birth	High temperatures are associated with preterm birth.
17	Cheng	2014	China	1990-2013	1941-2012	25	No		Adults, Elderly, Children	Meteorological	Infectious diseases Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes Health systems Other	Diurnal temperature range is associated with mortality and cardiovascular and respiratory outcomes, hospital admissions, and Hand Foot Mouth disease in children and genitourinary outcomes among the elderly.
18	Coates	2019	Denmark	2003-2018	NS	72	No			Meteorological	Infectious diseases	Some meteorological factors (temperature, humidity) are positively associated with Hand Foot Mouth disease (HFMD). Precipitation, wind speed and sunshine are not associated with HFMD.
19	Cong	2017	China	1994-2015	1982-2013	26	Yes			Meteorological	Respiratory, cardiovascular and	Temperature drop is associated with asthma.

											pulmonary, and neurological outcomes	
20	Cunrui	2011	Australia	1997-2010	1961-2100	14	No			Meteorological	Mortality	Higher temperature is associated with heat-related mortality.
21	deSousa	2018	Brazil	1976-2016	NS	106	No			Meteorological	Infectious diseases Respiratory, cardiovascular and pulmonary, and neurological outcomes	Meteorological factors (e.g., temperature, precipitation) are associated with infectious diseases (e.g., dengue, malaria) and cardiovascular and respiratory outcomes.
22	Dhimal	2015	Nepal	1956-2014	1948-2098	50	No	Nepal		Meteorological	Infectious diseases	Higher temperatures are associated with the distribution of vector-borne diseases.
23	Doocy	2013	United States	1975-2011	1974-2008	60	No			Extreme weather	Mortality Other	Cyclones are associated with mortality (e.g., drowning) and injuries.
24	Duan	2019	China	2010-2018	2000-2016	51	Yes	Southeast and East Asia		Meteorological	Infectious diseases	Some meteorological factors (mean maximum temperature, rainfall, humidity and sunshine) are positively associated with Hand Foot Mouth disease (HFMD), whereas air pressure is negatively associated with this disease and wind speed is not associated with HFMD.
25	Fan	2015	China	2004-2013	1985-2012	33	Yes			Meteorological	Infectious diseases	Temperature is positively associated with transmission and incidence of Dengue.
26	Fernandez	2015	Australia	1995-2014	NS	83	No			Extreme weather	Mental health	Floods are associated with negative mental health outcomes (e.g., PTSD, increased anxiety, depression, use of psychotropic medication). Conflicting evidence concerning suicide, tobacco, alcohol and substance abuse.
27	Flouris	2018	Greece	1954-2018	NS	111	Yes		Workers	Meteorological	Occupational health and injuries	High temperatures are positively associated with occupational heat

												strains, dehydration, kidney diseases and injuries.
28	Gao	2019	China	1994-2018	1969-2015	16	Yes			Meteorological	Mental health	Temperature increase is associated with suicide. No association between sunlight duration and suicide.
29	Gao	2014	China	1996-2012	1971-2010	37	No		Children	Meteorological	Infectious diseases Respiratory, cardiovascular and pulmonary, and neurological outcomes Skin and allergies	Ambient humidity is associated with gastrointestinal, respiratory and allergic diseases in children.
30	Ghanizadeh	2017	Iran	2009-2016	1990-2015	13	No			Meteorological	Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes	Meteorological factors, such as temperature and humidity, are associated with cardiopulmonary health. Cold temperatures are also associated with mortality from heart diseases.
31	Ghazani	2018	Australia	2006-2017	1991-2011	11	No			Meteorological	Infectious diseases	Higher temperature is associated with bacterial gastrointestinal infections. Humidity and rainfall may influence this association.
32	Gracia	2015	Sweden	2003-2011	1959-2008	9	No	Europe		Meteorological	Infectious diseases	Temperature is positively associated with Human Puumala Hantavirus in some regions of Europe. Results concerning precipitation and humidity are contradictory or null.
33	Hajat	2010	United Kingdom	1994-2008	1973-2003	11	No			Meteorological	Mortality	Ambient heat is associated with mortality.
34	Hedlund	2014	Sweden	1970-2012	1750-2009	29	No	Arctic, sub-Arctic	Vulnerable populations	Meteorological Extreme weather	Infectious diseases	Higher temperatures and flooding are associated with food- and water-borne diseases. This association is weaker for vector- and rodent-borne diseases. Air

												temperature and humidity seem to be associated with air-borne diseases.
35	Hii	2016	Sweden	2007-2015	2003-2012	9	No	Malaysia		Meteorological	Infectious diseases	Some meteorological factors (temperature, rainfall and humidity) are associated with Dengue, although these associations are inconsistent at times.
36	Huang	2016	Taiwan	1990-2014	1978-2011	19	Yes			General	Skin and allergies	Climate change, in general, may be associated with skin and soft-tissue infections.
37	Kampe	2016	United Kingdom	1998-2015	1971-2010	13	No	High-income countries		Meteorological	Other	Higher temperature is associated with unintentional injuries.
38	Khader	2015	Jordan	2003-2014	1991-2012	78	No	Eastern Mediterranian	Vulnerable countries	Meteorological Extreme weather Air quality	Infectious diseases Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes Health systems Mental health Pregnancy and birth Dietary	High temperature is associated with mortality. Temperature, humidity and precipitation are associated with vector-, food- and water-borne diseases. Air pollution is associated with respiratory outcomes, although some findings are inconsistent. Higher temperature is associated with mental health outcomes and hospital admissions. Higher temperature may also be associated with adverse birth outcomes. Meteorological and extreme weather events are associated with food insecurity.
39	Klinger	2014	United Kingdom	2011-2013	NS	20	No			Extreme weather	Health systems	Extreme weather events may lead to power outages which may pose challenges to healthcare quality.
40	Kuehn	2017	United States	2002-2017	NS	28	No		Pregnant people	Meteorological	Pregnancy and birth	Extreme heat exposure is associated with adverse birth outcomes (e.g. stillbirth, birth weight).
41	Lake	2017	United Kingdom	NS	NS	66	No	Europe		General	Skin and allergies	Climate change may be associated with ragweed pollen allergy.

42	Lal	2019	Australia	1982-2011	NS	36	Yes		Children	Meteorological	Infectious diseases	Rainfall is associated with childhood diarrhea, although this association differed according to season and latitude.
43	Lal	2015	Australia	NS	NS	16	No	New Zealand		Meteorological	Infectious diseases	Temperature variability, higher temperature and rainfall are associated with enteric diseases.
44	Lawton	2019	Australia	2000-2015	NS	71	No			Meteorological	Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes	Heat exposure is associated with heat stroke, long-term neurological outcomes (e.g., cerebellar injury) and heat-related mortality.
45	Levi	2018	Italy	2003-2017	1977-2014	184	No		Workers	Meteorological	Occupational health and injuries	Heat exposure is associated with occupational injuries.
46	Levy	2016	United States	1972-2013	1948-2010	208	No			Meteorological Extreme weather	Infectious diseases	Temperature is associated with bacterial diarrhea and drought is associated with all-cause diarrhea, although few studies explored the association between drought and diarrhea.
47	Leyva	2017	Asia	2009-2017	NS	30	No		Elderly	Meteorological Extreme weather Air quality	Infectious diseases Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes Health systems Mental health	Meteorological factors, extreme weather events (e.g. typhoon, floods) and air pollution are associated with mortality and morbidity, especially cardiovascular- and respiratory-specific. Higher temperature is associated with vector-borne diseases. Heat and cold temperatures are associated with hospital admissions. Flooding is associated with mental health outcomes (e.g. PTSD, depression).
48	Li	2018	China	1988-2017	NS	81	No	China		Meteorological	Infectious diseases	Meteorological factors (temperature, precipitation, humidity, air pressure) and extreme weather events (floods,

										Extreme weather		typhoons) are associated with Dengue fever in China.
49	Lian	2015	China	2003-2014	NS	20	Yes			Meteorological	Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes	Higher and lower temperatures are associated with stroke-related mortality and low temperatures are also associated with stroke-related morbidities.
50	Liu	2015	United States	1990-2014	NS	61	No			Air quality	Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes Health systems Pregnancy and birth Other	Wildfire smoke exposure is associated with mortality, respiratory outcomes and hospital admissions. Wildfire smoke exposure could also be associated with cardiovascular, ophthalmic and pregnancy outcomes, although more research is needed.
51	Madaniyazi	2015	Australia	2004-2013	1961-2100	15	No			Air quality	Mortality	Air pollution is associated with future mortality.
52	Matysiak	2017	Puerto Rico	2001-2005	NS	26	No	Puerto Rico (United-States)		Meteorological Extreme weather	Infectious diseases	Meteorological factors (higher temperature and increased rainfall) are associated with vector-borne diseases, such as Dengue and Zika. Extreme weather events are less researched, but the few studies investigating this association suggest no association between hurricanes and floods and vector-borne diseases.
53	Moghadamnia	2017	Iran	2011-2016	1979-2013	26	Yes			Meteorological	Mortality	Higher and lower temperature are associated with cardiovascular mortality.
54	Naish	2014	Australia	NS	1931-2010	16	No			Meteorological	Infectious diseases	Meteorological factors (especially temperature, rainfall and humidity) are associated with Dengue.

55	Nichols	2009	United Kingdom	1999-2008	NS	36	No			Meteorological Extreme weather Air quality	Infectious diseases Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes Mental health Dietary Skin and allergies Other	Meteorological factors (e.g., higher temperature) are associated with mortality and various infectious diseases. Increased UV exposure is associated with skin cancer and cataracts. Extreme weather events are associated with mortality, injury, mental health outcomes, malnutrition, and food- and water-borne diseases. Air pollution is associated with cardio-respiratory outcomes.
56	Odame	2018	United States	2006-2017	1893-2013	14	Yes		Rural populations	Meteorological	Mortality	Higher temperature is associated with all-cause mortality and cardiovascular specific mortality.
57	Park	2017	Korea	1920-2015	1961-2013	10	Yes			Meteorological	Other	Higher temperature is associated with acute gouty arthritis.
58	Phalkey	2015	Germany	1989-2012	1982-2008	15	No	Low to middle-income countries	Children	Meteorological Extreme weather	Dietary	Meteorological factors (rainfall, temperature) and extreme weather events are associated with childhood undernutrition.
59	Philipsborn	2016	Georgia	NS	1973-2010	28	Yes			Meteorological	Infectious diseases	Higher temperature is associated with Diarrheagenic Escherichia coli. No significant relationship between rainfall and E. coli.
60	Phung	2015	Australia	2004-2013	NS	13	No	Southeast Asia		Meteorological Extreme weather	Infectious diseases	Meteorological factors (temperature, humidity) and extreme weather events (flooding) are associated with vector- and water-borne infectious diseases.
61	Porpora	2019	Italy	1964-2019	NS	78	No			Other	Pregnancy and birth	Environmental pollutants may be associated with preterm birth, however this association remains unclear due to conflicting evidence.
62	Poursafa	2015	Iran	2001-2013	NS	15	No			Meteorological	Pregnancy and birth	Meteorological factors (higher temperature, lower temperature, humidity, sunlight intensity) are

												associated with adverse birth outcomes (low birth weight, preterm birth, hypertension, eclampsia).
63	Racloz	2012	Australia	NS	NS	63	No			Meteorological	Infectious diseases	Higher temperature, increased precipitation and humidity are associated with Dengue.
64	Rataj	2016	Germany	1981-2012	1978-2008	17	No	Low to middle income countries		Extreme weather	Mental health Other	Extreme weather events are associated with mental health outcomes (e.g., PTSD, anxiety, depression) and injuries.
65	Reid	2016	United States	1990-2015	NS	53	No		Susceptible populations	Air quality	Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes Mental health Pregnancy and birth	Wildfire smoke exposure is associated with respiratory outcomes (e.g., asthma) and mortality. Wildfire smoke exposure may be associated with cardiovascular, birth, and mental health outcomes, but more research is needed.
66	Rifkin	2018	United States	1995-2017	1992-2016	16	No			Meteorological Extreme weather	Other	Temperature and extreme weather events (hurricanes) are associated with sleep quality.
67	Salve	2018	India	NS	NS	11	No	India		Meteorological	Mortality Health systems Dietary	Increase in temperature is associated with all-cause mortality, cause-specific mortality (e.g., myocardial infarctions, stroke, heart diseases), hospitalizations (e.g., heat-related admissions, neonatal intensive unit admissions), and food insecurity and malnutrition, via agricultural issues.
68	Sanderson	2017	United Kingdom	1988-2017	1900-2101	63	No			Meteorological	Mortality	Higher temperatures and heat waves are associated with mortality and heat-related mortality is likely to increase with increased temperatures.
69	Sawatzky	2018	Canada	2005-2016	NS	85	No	Arctic and		General	Health systems	Climate change, in general, is associated with a strain in public

								Subarctic				health resources, via population health issues and surveillance systems may guide future adaptation to climate change.
70	Semenza	2012	Sweden	1998-2009	1995-2007	722	No			Meteorological	Infectious diseases	Meteorological factors (temperature, rainfall) are associated with some food- and water-borne diseases.
71	Stanke	2013	United Kingdom	1967-2011	1876-1879 and 1961-2010	87	No			Extreme weather	Infectious diseases Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes Mental health Dietary Other	Droughts are associated with malnutrition, mortality, infectious diseases, cardiovascular and respiratory outcomes, mental health (e.g., increased worry, anxiety), injuries, and cancer.
72	Stensgaard	2019	Denmark	1995-2017	NS	20	No			Meteorological	Infectious diseases	Meteorological factors (temperature, precipitation, humidity) are associated with schistosomiasis and increasing temperatures are likely to affect the geographic range of this parasite.
73	Sun	2018	China	1999-2017	1974-2014	30(review)23meta-analysis	Yes			Meteorological	Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes Health systems	Heat and cold exposure are associated with myocardial infarctions (MI) and hospitalization for MI. Heat exposure is associated with MI-specific mortality.
74	Swynghedauw	2009	France	NS	NS	NS	No			Meteorological Extreme weather	Infectious diseases Mortality Skin and allergies	Heat and cold exposure are associated with mortality and more specifically, respiratory- and cardiovascular-specific mortality. Exposure to UV is associated with skin cancer and

											Other	cataracts. Higher temperatures are associated with infectious diseases (mosquito- and food-borne diseases) and extreme weather events are associated with undernutrition and food-borne diseases.
75	Tall	2014	Australia	1946-2009	1886-2006	22	No	Australia		Extreme weather	Infectious diseases	There is no strong evidence for the association between flooding and the Ross River Virus.
76	Varghese	2018	Australia	1983-2017	1922-2017	26	No		Workers	Meteorological	Occupational health and injuries	Heat is associated with occupational injuries in many contexts of work (e.g., agriculture, transport, construction, fishing).
77	Veenema	2017	United States	2006-2016	NS	47	No			Extreme weather	Infectious diseases Mortality Mental health	Extreme water-related weather events are associated with mortality, water- and vector-borne infectious diseases, mental health issues (e.g., PTSD, depression, anxiety).
78	Vilcins	2018	Australia	NS	NS	72	No		Children	Other	Dietary	Certain environmental risk factors (e.g., sanitation, cooking fuels), which could be aggravated by climate change, may be associated with childhood stunting.
79	Vins	2015	United States	1995-2005	NS	82	No			Extreme weather	Mental health	Drought is likely associated with adverse mental health outcomes.
80	Waits	2018	Finland	1970-2017	NS	43	No	Arctic		Meteorological	Infectious diseases	Meteorological factors (especially higher temperature and precipitation) are associated with infectious diseases (e.g. tick borne diseases, tularemia) in the Arctic.
81	Wald	2019	United States	2009-2018	NS	17	No	United States		Meteorological	Health systems	Higher temperature is associated with emergency department (heat-related visits) visits and costs for healthcare systems.
82	Welch	2019	United States	NS	NS	91	No			Meteorological	Infectious diseases	Meteorological factors (temperature, precipitation) are associated with Salmonella.
83	Wimalawansa	2016	United States	NS	NS	NS	No	Tropical	Workers	Meteorological Other	Occupational health and injuries	Increasing temperatures and environmental pollution (e.g., heavy metals, fertilizers) are associated with

								Countries				occupational health outcomes, such as chronic kidney disease of multifactorial origin.
84	Witt	2015	Germany	NS	NS	33	Yes		Chronic lung disease patients	Meteorological	Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes	Heat is associated with lung disease outcomes and mortality in patients with chronic lung diseases.
85	Xu	2018	Australia	2004-2016	1978-2013	19	No		Children	Meteorological	Respiratory, cardiovascular and pulmonary, and neurological outcomes	Heat and cold temperatures are associated with childhood asthma.
86	Xu	2012	Australia	2000-2012	1983-2010	33	No		Children	Meteorological	Infectious diseases Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes Health systems Skin and allergies Other	Heat and cold are associated with hospital admissions and mortality in children. Temperature is also associated with various infectious diseases (e.g., HFMD, malaria), respiratory diseases (e.g., asthma) and skin outcomes (e.g, eczema). For example, high temperature is associated with Hand Foot Mouth Disease and renal diseases and low temperature is associated with eczema.
87	Xu	2016	Australia	2001-2015	NS	60	Yes			Meteorological	Mortality	Heat waves are associated with mortality and it seems that the intensity of heatwaves is particularly important compared to length of heatwave.
88	Xu	2014	Australia	1998-2012	1983-2009	12	No		Children	Meteorological	Mortality	Heat waves are associated with hospital admissions, respiratory

											Respiratory, cardiovascular and pulmonary, and neurological outcomes Health systems Other	diseases, renal diseases, fever and electrolyte imbalances. Evidence concerning the association between heatwaves and children mortality is inconsistent.
89	Youssouf	2014	France	1990-2011	1987-2008	94	No			Air quality	Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes Health systems Pregnancy and birth	Wildfire smoke exposure is associated with mortality, respiratory and cardiovascular outcomes, hospital admissions. Wildfire smoke exposure may also be associated with adverse birth outcomes (low birth weight).
90	Yu	2015	Australia	1998-2012	1961-1990 et 2020-2100	20	No			Meteorological	Infectious diseases	Meteorological factors (temperature, rainfall, humidity) may be associated with future malaria transmission, although findings are inconsistent, partly according to geographical focus.
91	Yu	2012	Australia	1997-2008	1973-2006	15	Yes		Elderly	Meteorological	Mortality	Heat and cold temperatures are associated with mortality for the elderly, although heat-related associations seem stronger than cold-related associations.
92	Zhang	2007	Australia	NS	NS	NS	No		People with disabilities	General	Other	Climate change, in general, may be associated with disability-adjusted life years (DALY), and the cost of DALY could be particularly important in low to middle income countries.
93	Zhang	2017	China	1997-2016	1981-2012	36	No		Pregnant people	Meteorological	Pregnancy and birth	High temperature is associated with adverse birth outcomes, such as preterm birth, low birth weight and

												stillbirth. Low temperature is also associated with some adverse birth outcomes, including preterm birth and low birth, although the evidence is stronger for high temperature than for low temperatures.
94	Zuo	2015	Australia	NS	NS	173	No			Meteorological	Mortality Respiratory, cardiovascular and pulmonary, and neurological outcomes Health systems Mental health Skin and allergies Other	Heat waves are associated with mortality, hospital admissions, sunburn, heat exhaustion, cardiovascular outcomes (e.g., heart attacks) and mental health outcomes.

*NS = non-specified

Appendix 4. Summary of quality assessment according to revised AMSTAR-2 items. (Y = yes, PY = partial yes, N = no, NA = non-applicable).

		AMSTAR-2 Items																
First author	**Year**	**1**	**1b**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Alderman	2012	Y	N	N	PY	PY	N	N	PY	PY	N	N	NA	NA	Y	N	NA	N
Amegah	2016	Y	N	N	Y	PY	N	N	PY	Y	Y	N	NA	NA	Y	Y	NA	Y
An	2018	N	Y	N	N	PY	Y	N	Y	N	Y	N	NA	NA	Y	N	NA	Y
Augustin	2008	Y	Y	N	N	PY	N	N	PY	N	PY	N	NA	NA	Y	N	NA	Y
Babaie	2018	Y	Y	N	N	PY	Y	N	Y	PY	N	N	NA	NA	N	N	NA	N
Bai	2013	Y	Y	N	PY	PY	N	N	PY	PY	Y	N	NA	NA	Y	N	NA	Y
Benevolenza	2019	Y	Y	N	PY	N	N	N	Y	PY	PY	N	NA	NA	Y	N	NA	N
Berhane	2016	Y	N	Y	N	N	N	N	N	PY	PY	N	NA	NA	Y	N	NA	N
Bernhardt	2019	Y	N	N	N	N	N	N	PY	PY	PY	N	NA	NA	PY	N	NA	Y
Binazzi	2019	Y	Y	N	Y	PY	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Bonafede	2016	Y	N	N	PY	PY	Y	N	Y	Y	Y	N	NA	NA	Y	Y	NA	Y
Brown	2013	Y	Y	N	PY	PY	N	N	Y	Y	PY	N	NA	NA	Y	Y	NA	Y
Bunker	2016	Y	Y	N	Y	N	Y	PY	Y	Y	PY	N	Y	Y	Y	Y	Y	Y
Campbell	2018	Y	N	N	N	PY	N	N	Y	PY	N	N	NA	NA	Y	PY	NA	Y
Cann	2013	Y	Y	Y	PY	PY	N	N	Y	PY	PY	N	NA	NA	Y	Y	NA	Y
Carolan-Olah	2014	Y	Y	N	N	PY	N	N	Y	PY	Y	N	NA	NA	PY	PY	NA	N
Cheng	2014	Y	N	N	PY	PY	N	N	Y	Y	Y	N	NA	NA	Y	PY	NA	N
Coates	2019	N	N	N	N	N	N	N	PY	PY	Y	N	NA	NA	Y	PY	NA	N
Cong	2017	N	Y	N	N	PY	N	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y
Cunrui	2011	Y	N	N	PY	PY	N	N	Y	PY	N	N	NA	NA	Y	N	NA	Y
deSousa	2018	Y	N	N	PY	PY	N	N	Y	N	N	N	NA	NA	Y	N	NA	Y
Dhimal	2015	Y	Y	N	PY	PY	N	N	Y	Y	N	N	NA	NA	N	N	NA	N
Doocy	2013	Y	N	N	N	PY	Y	N	Y	Y	N	N	NA	NA	Y	PY	NA	Y
Duan	2019	Y	N	N	N	PY	N	N	Y	PY	Y	N	Y	Y	Y	Y	Y	Y
Fan	2015	N	Y	N	N	PY	Y	Y	PY	PY	Y	N	Y	Y	Y	Y	Y	Y
Fernandez	2015	Y	Y	N	PY	PY	Y	N	Y	PY	PY	N	NA	NA	Y	N	NA	N
Flouris	2018	Y	N	Y	PY	PY	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Gao	2019	N	Y	N	PY	PY	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y

Gao	2014	Y	N	N	PY	PY	N	PY	Y	Y	Y	N	NA	NA	Y	Y	NA	Y
Ghanizadeh	2017	N	Y	N	PY	N	Y	PY	Y	PY	Y	N	NA	NA	N	N	NA	Y
Ghazani	2018	N	N	N	N	PY	Y	N	Y	Y	PY	N	NA	NA	Y	PY	NA	Y
Gracia	2015	Y	Y	N	PY	PY	Y	N	Y	PY	Y	N	NA	NA	Y	N	NA	Y
Hajat	2010	Y	N	N	Y	PY	N	N	Y	PY	N	N	NA	NA	N	PY	NA	Y
Hedlund	2014	Y	N	N	PY	N	Y	Y	Y	PY	Y	N	NA	NA	Y	N	NA	Y
Hii	2016	Y	N	N	PY	PY	N	N	PY	PY	N	N	NA	NA	N	N	NA	Y
Huang	2016	N	N	N	N	PY	Y	N	PY	Y	Y	N	Y	Y	Y	PY	N	Y
Kampe	2016	Y	N	N	PY	PY	Y	N	Y	Y	PY	N	NA	NA	Y	N	NA	Y
Khader	2015	Y	N	N	PY	PY	Y	N	Y	Y	N	N	NA	NA	Y	PY	NA	Y
Klinger	2014	N	N	N	N	PY	Y	N	Y	N	Y	N	NA	NA	Y	N	NA	Y
Kuehn	2017	Y	N	N	N	PY	N	N	Y	Y	PY	N	NA	NA	Y	N	NA	Y
Lake	2017	Y	Y	N	N	PY	Y	Y	PY	PY	N	N	NA	NA	N	N	NA	Y
Lal	2019	Y	N	Y	N	PY	N	Y	Y	PY	Y	N	Y	Y	Y	Y	N	Y
Lal	2015	Y	Y	N	N	PY	N	N	Y	PY	PY	N	NA	NA	Y	PY	NA	Y
Lawton	2019	Y	N	N	PY	PY	N	N	Y	Y	N	N	NA	NA	Y	N	NA	Y
Levi	2018	Y	Y	N	PY	PY	Y	N	Y	Y	N	N	NA	NA	Y	PY	NA	Y
Levy	2016	N	N	N	PY	PY	Y	PY	Y	Y	Y	N	NA	NA	Y	Y	NA	Y
Leyva	2017	Y	Y	N	PY	PY	N	N	Y	N	Y	N	NA	NA	Y	N	NA	N
Li	2018	Y	N	N	N	PY	N	N	N	PY	N	N	NA	NA	N	N	NA	Y
Lian	2015	Y	N	N	PY	PY	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y
Liu	2015	Y	Y	N	Y	PY	N	N	Y	Y	PY	N	NA	NA	Y	PY	NA	Y
Madaniyazi	2015	N	N	N	PY	PY	N	N	Y	PY	N	N	NA	NA	Y	N	NA	Y
Matysiak	2017	Y	Y	N	PY	PY	N	N	Y	PY	Y	N	NA	NA	Y	N	NA	Y
Moghadamnia	2017	Y	N	N	PY	PY	Y	N	Y	Y	Y	N	Y	N	Y	Y	N	Y
Naish	2014	Y	Y	N	PY	PY	N	N	PY	PY	PY	N	NA	NA	Y	N	NA	Y
Nichols	2009	Y	N	N	PY	PY	Y	Y	Y	Y	N	N	NA	NA	N	N	NA	Y
Odame	2018	Y	N	N	PY	PY	N	N	PY	PY	N	N	Y	N	Y	Y	Y	Y
Park	2017	Y	N	N	N	PY	Y	Y	N	PY	Y	N	Y	PY	Y	Y	N	Y
Phalkey	2015	Y	Y	N	PY	PY	Y	Y	Y	PY	PY	N	NA	NA	Y	N	NA	Y
Philipsborn	2016	Y	Y	N	PY	N	N	N	Y	PY	N	N	Y	Y	N	Y	N	Y
Phung	2015	Y	Y	N	N	PY	N	N	Y	Y	PY	Y	NA	NA	N	N	NA	Y

Porpora	2019	Y	Y	Y	PY	PY	N	N	Y	PY	N	N	NA	NA	N	Y	NA	Y
Poursafa	2015	Y	N	N	PY	PY	Y	Y	PY	Y	PY	N	NA	NA	Y	Y	NA	Y
Racloz	2012	Y	N	N	N	PY	N	N	N	PY	N	N	NA	NA	Y	Y	NA	Y
Rataj	2016	Y	Y	Y	PY	PY	Y	Y	PY	PY	Y	N	NA	NA	Y	Y	NA	Y
Reid	2016	Y	N	N	PY	PY	N	N	N	PY	PY	N	NA	NA	Y	PY	NA	Y
Rifkin	2018	Y	Y	Y	PY	PY	Y	Y	Y	PY	N	N	NA	NA	Y	N	NA	Y
Salve	2018	Y	Y	N	N	PY	Y	Y	PY	PY	N	N	NA	NA	Y	N	NA	Y
Sanderson	2017	Y	Y	N	N	PY	Y	N	Y	PY	PY	N	NA	NA	Y	N	NA	Y
Sawatzky	2018	Y	Y	N	N	PY	Y	N	Y	N	N	N	NA	NA	N	N	NA	Y
Semenza	2012	N	N	N	N	N	N	N	N	N	Y	N	NA	NA	N	N	NA	N
Stanke	2013	Y	N	N	PY	PY	N	N	Y	PY	N	N	NA	NA	Y	N	NA	Y
Stensgaard	2019	Y	Y	N	N	PY	N	Y	N	PY	N	N	NA	NA	N	N	NA	Y
Sun	2018	Y	Y	N	PY	PY	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Swynghedauw	2009	Y	Y	N	N	N	N	N	N	N	N	N	NA	NA	N	N	NA	Y
Tall	2014	Y	N	N	N	PY	N	N	Y	Y	PY	N	NA	NA	Y	N	NA	Y
Varghese	2018	Y	N	N	N	PY	N	N	Y	Y	N	N	NA	NA	Y	N	NA	Y
Veenema	2017	Y	N	Y	N	PY	N	N	Y	N	PY	N	NA	NA	N	N	NA	N
Vilcins	2018	Y	N	Y	N	PY	N	N	Y	N	Y	N	NA	NA	Y	N	NA	Y
Vins	2015	Y	Y	N	N	PY	N	N	Y	N	N	N	NA	NA	Y	PY	NA	Y
Waits	2018	Y	Y	N	N	PY	N	N	Y	N	N	N	NA	NA	N	N	NA	Y
Wald	2019	Y	N	N	N	PY	N	N	Y	Y	N	N	NA	NA	Y	N	NA	N
Welch	2019	Y	Y	N	N	N	N	N	PY	PY	N	N	NA	NA	N	N	NA	N
Wimalawansa	2016	Y	N	N	N	N	N	N	N	N	N	N	NA	NA	N	N	NA	Y
Witt	2015	Y	N	N	N	PY	N	N	Y	N	N	N	N	Y	Y	N	N	Y
Xu	2018	Y	N	N	PY	PY	N	N	PY	PY	N	N	NA	NA	Y	N	NA	Y
Xu	2012	Y	N	N	PY	PY	N	N	PY	Y	PY	N	NA	NA	N	N	NA	Y
Xu	2016	Y	N	N	PY	PY	N	N	Y	Y	N	N	Y	N	Y	Y	N	Y
Xu	2014	Y	Y	N	N	PY	N	N	Y	Y	N	N	NA	NA	N	Y	NA	N
Youssouf	2014	Y	Y	N	PY	PY	N	N	Y	Y	N	N	NA	NA	Y	N	NA	Y
Yu	2015	N	N	N	PY	PY	N	N	Y	Y	N	N	NA	NA	Y	PY	NA	Y
Yu	2012	Y	Y	N	PY	N	N	Y	Y	Y	N	N	Y	N	Y	Y	Y	Y
Zhang	2007	Y	N	N	N	N	N	N	N	N	N	N	NA	NA	Y	N	NA	N

Zhang	2017	Y	Y	N	PY	PY	N	N	PY	Y	Y	N	NA	NA	Y	Y	NA	Y
Zuo	2015	Y	Y	N	N	PY	N	N	N	N	N	N	NA	NA	N	N	NA	Y
TOTAL	Yes	81	44	9	5	0	32	17	64	36	31	2	17	12	70	28	11	78
	Partial Yes	0	0	0	47	80	0	4	19	41	22	0	0	1	2	15	0	0
	No	13	50	85	42	14	62	73	11	17	41	92	1	5	22	51	7	16
	Not-Applicable	0	0	0	0	0	0	0	0	0	0	0	76	76	0	0	76	0

Appendix 5. Summary table of publications according to climate impact and health outcome according to frequencies and references. References with a * explore only this specific combination of climate impact and health outcome and therefore appear only once in this table. Number of studies and references (according to alphabetical order) for each combination of categories are presented in the cells. Empty cells in this Table indicate an absence of studies at this combination of categories.

Health Outcome	Climate Impact				
	Meteorological (71)	Extreme weather (24)	Air quality (7)	General (5)	Other (3)
Infectious diseases (41)	**35** Amegah, Babaie*, Bai*, Berhane, Bernhardt*, Cheng, Coates*, de Sousa, Dhimal*, Duan*, Fan*, Gao 2014, Ghazani*, Gracia*, Hedlund, Hii*, Khader, Lal 2015*, Lal 2019*, Levy, Leyva, Li, Matysiak, Naish*, Nichols, Philipsborn*, Phung, Racloz*, Semenza*, Stensgaard, Swynghedau, Waits*, Welch*, Xu 2012, Yu 2015*	**14** Alderman, Berhane, Brown*, Cann*, Hedlund, Levy, Li, Matysiak, Nichols, Phung, Stanke, Swynghedau, Tall*, Veenema			
Mortality (32)	**24** Amegah, Bunker, Campbell, Cheng, Cunrui*, Ghanizadeh, Hajat*, Khader, Lawton, Leyva, Lian, Moghdamnia*, Nichols, Odame*, Salve, Sanderson*, Sun, Swynghedauw, Witt, Xu 2012, Xu 2014, Xu 2016*, Yu 2012*, Zuo	**5** Alderman, Doocy, Leyva, Stanke, Veenema	**5** Leyva, Liu, Madniyazi*, Reid, Youssouf		
Respiratory, cardio-vascular, cardio-pulmonary and neurological (22)	**17** Amegah, Bunker, Cheng, Cong*, de Sousa, Gao 2014, Ghanizadeh, Lawton, Leyva, Lian, Nichols, Sun, Witt, Xu 2012, Xu 2014, Xu 2018*, Zuo	**1** Stanke	**6** Khader, Leyva, Liu, Nichols, Reid, Youssouf		

Health systems (16)	**11** Amegah, Campbell, Cheng, Khader, Leyva, Salve, Sun, Wald*, Xu 2012, Xu 2014, Zuo	**2** Alderman, Klinger*	**2** Liu, Youssouf	**1** Sawatzky*	
Mental Health (13)	**3** Gao 2019*, Khader, Zuo	**9** Alderman, Benevolenza, Fernandez*, Leyva, Nichols, Rataj, Stanke, Veenema, Vins*	**1** Reid		
Pregnancy and birth outcomes (11)	**5** Carolan-Olah*, Kuehn*, Poursafa*, Khader, Zhang 2017*	**2** Alderman, Benevolenza	**3** Liu, Reid, Youssouf		**1** Porpora*
Dietary (9)	**4** Amegah, Khader, Phalkey, Salve	**6** Berhane, Khader, Nichols, Phalkey, Stanke, Swynghedauw		**1** An*	**1** Vilcins*
Skin and allergies (9)	**7** Amegah, Augustin*, Nichols, Gao 2014, Swynghedauw, Xu 2012, Zuo			2 Huang*, Lake*	
Occupational health and injuries (6)	**6** Binazzi*, Bonafede*, Flouris*, Levi*, Varghese*, Wimalawans				**1** Wimalawans
Other (17)	**10** Bunker, Cheng, Kampe*, Nichols, Park*, Rifkin, Swynghedauw, Xu 2012, Xu 2014, Zuo	**6** Alderman, Benevolenza, Doocy, Rataj, Rifkin, Stanke	**1** Liu	**1** Zhang 2007*	