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Health and migration in the context of a changing climate: a systematic literature assessment

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Supplementary material for this article is available [online](#)

Abstract

Background. Climate change and climate variability interact with political, economic, social, demographic, and other environmental drivers to change the scale and patterns of human migration⁵. In the context of accelerating climate change and breaches to other planetary boundaries, there is an urgent need to better understand how migrant health can be protected and promoted in the context of a changing climate to manage safe and orderly migration⁶. While research has focused on the separate dyads of (i) climate change and migration and (ii) climate change and health, limited consideration has been given to the nexus between climate change, migration, and health. This assessment synthesizes research that has investigated this relationship since 1990. **Methods.** Following an *a priori* protocol and with the assistance of a subject librarian, systematic searches were conducted in four academic databases (PubMed, Scopus, Ovid Medline, and Global Health) and Google Scholar for empirical studies investigating migration and health in the context of climate change with any study design between 1990 and 2018. The search results underwent a two-stage screening process and the eligible studies were subjected to quality appraisal using a mixed methods appraisal tool. Data extraction and a meta-synthesis followed producing outputs deemed most useful for policy, practice, and further research. **Findings.** The registered protocol and search strategy revealed 1904 studies of which 180 were screened in full-text and 50 were included in the meta-synthesis. Overall, the methodological and reporting quality of the included studies was high. This assessment produced five main findings: (1) there is a paucity of empirical research investigating the climate-health-migration nexus; (2) the relationships between migration and health in the context of climate change are strongly heterogeneous and global findings are unlikely to emerge; (3) studies have examined diverse health issues associated with migration in the context of climate change including changing patterns of infectious disease, non-communicable disease, psychosocial conditions, and access to health care; (4) food and water security are important mediators between climate change, human mobility and health outcomes; (5) there is no consistent approach to integrating climate data in studies exploring migration and health in the context of climate change.

⁵ Mobility is used as an over-arching term for the movement of people. Migration is defined as movement across an international border or within a state away from a habitual place of residence, regardless of legal status, degree of choice, causes of the movement, or the length of stay (IOM 2019a).

⁶ Wording from the Global Compact for Safe, Orderly and Regular Migration (UNHCR 2018b).

Conclusions. Although migrant health and climate-related health risks are significant population health concerns, there has been limited consideration of the complex connections between climate change, migration, and health. This assessment indicates that there are potentially important intersections between climate-health- migration and that further research is required to better understand this nexus. To date and based on this assessment, it seems important that research and policy related to migration also consider the links between climate change and health and that migration is considered a determinant of health in climate change and health research. Given the diverse mobility patterns that arise in the context of climate change, responsive approaches are required that address the vulnerabilities of communities at risk of, or involved in forced migration, whilst supporting the adaptive potential of mobility responses. There is a need to develop policies that are responsive enough to protect health and health determinants especially food and water security regardless of the climate scenario. The degree to which climate data are meaningfully integrated into research exploring migration and health in the context of a changing climate warrants further consideration and analysis, to maintain quality in this emerging field of nexus research. Health systems that are migrant inclusive and climate-resilient have the potential to mitigate the worst health impacts of climate-related migration.

1. Introduction

In the 200 thousand years that humans have inhabited this 4.5 billion-year-old planet, migration has been a necessary and strategic response to environmental changes and natural hazards. Yet, anthropogenic climate change is reshaping patterns of human mobility. Sudden onset climate shocks (e.g.—cyclones) and slow-onset climate stresses (e.g.—sea level rise) may have different health consequences for mobile populations at all stages of the migration journey, as well as for communities at origin and host communities (McMichael *et al* 2012, Schwerdtle *et al* 2018). Just as climate change acts to amplify existing health issues, so too does it influence political, economic, demographic, social, and environmental drivers of migration, which are unique to each context and population (Black *et al* 2011).

With one billion people on the move or having moved in 2018, migration is a global reality (Abubakar *et al* 2018). International migration has increased to 258 million people yet three times that number, roughly 763 million, move within their countries of birth including those searching for improved livelihoods and those internally displaced due to climate change, environmental degradation, violence and conflict (Abubakar *et al* 2018, Vearey *et al* 2019).

Whilst climate change is considered an important driver of migration, the term ‘climate-migrant’ and its synonyms remain legally and scientifically

contested. Quantitative estimates of future climate-change-related migration are diverse and debated. Estimates depend on emissions trajectories, tipping points, population growth, mitigation and adaptation measures and international migration governance as well as on the methodology and datasets employed. Some estimates are in the order of hundreds of millions of climate-related migrants by mid-century (Gemenne 2011). Recent estimates indicate 140 million people will be internally displaced by climate change in Sub Saharan Africa, South Asia, and Latin America alone by 2050 (Rigaud *et al* 2018). However, these estimates are often based on population exposure to environmental hazards and do not adequately account for social and economic modifiers and adaptive capacities. Confidence in global and regional estimates of the climate-migration nexus remains low, although modeling efforts are increasingly sophisticated (Rigaud *et al* 2018).

In terms of the political context, the principle of ‘leaving no one behind’ is central to the Sustainable Development Goals (SDGs). There is an acknowledgment that universal health coverage can only be attained by including migrants (Vearey *et al* 2019). At the United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties (COP) 21 in Paris, a task force was established to make recommendations regarding how to address climate-related displacement (United Nations 2017a). The Platform on Disaster Displacement, the follow-up process to the Nansen Initiative, aims to implement

the protection agenda for cross-border displaced persons (United Nations 2017b) and the Sendai Framework for Disaster Risk Reduction explicitly recognizes population displacement and planned relocation as key policy issues (United Nations 2015, Grecequet *et al* 2017, Dannenburg *et al* 2019). The Global Compact on Refugees (UNHCR 2018b) and the Global Compact for Migration (UNHCR 2018a) represent the ambitions of the international community and political will for strengthened cooperation and solidarity with migrants and affected host countries. The Global Compact for Migration has a specific objective on addressing the adverse drivers and structural factors including the impacts of climate change and disasters (UNHCR 2018a).

There exists a large body of scholarship and research on climate change and migration, which dates back three decades (Tickell 1990, Myers 1993, Myers 2002, Gemenne 2011, Marchiori and Schumacher 2011, Gray and Mueller 2012, Bohra-Mishra *et al* 2014, Mcleman 2014, Zickgraf *et al* 2016, Grace *et al* 2018, Piguet *et al* 2018). The literature on climate change and health has a comparable history and whilst showing increasing theoretical and methodological sophistication, lacks coverage of contexts where exposure is the highest and capacity the lowest (Herlihy *et al* 2016, Sauerborn 2017). To date, findings indicate that local environmental conditions interact with socio-economic, cultural, and political circumstances to influence migration decision-making, patterns, and health outcomes (IPCC 2014, Hunter and Simon 2017, Schwerdtle *et al* 2018). Studies have variously characterized climate-related migration as a last resort (Warner *et al* 2010, Laczko and Piguet 2014), a successful adaptation strategy, or a failure to adapt *in situ* (Tacoli 2009, Bardsley and Hugo 2010, Gemenne 2013). There is a growing concern with trapped or immobile populations who are unable or unwilling to move in the face of climate stressors (Zickgraf *et al* 2016, Adams 2016, Hirvonen 2016).

The scope of this assessment is an evidence synthesis for climate change—migration—health nexus. Climate change-related migration is a specific and thus, a narrower form of environmental migration. A thorough pre-protocol search was conducted to ensure no similar evidence synthesis existed. We consulted the Cochrane handbook for guidelines on reporting systematic reviews and followed the FINER criteria (feasible, interesting, novel, ethical and relevant) for developing the research question including checking for pre-existing reviews or syntheses (Cummings *et al* 2013, Thomas *et al* 2019). We performed a search in Prospero and Joanna Briggs Institute using keywords: climate change, migration, and health as well as consulting bibliographic databases; OVID Medline, Embase, Web of Science and CINAHL, and applying a publication limit of ‘systematic review’.

The authors concluded that no other review with the proposed criteria existed at the time of the search.

Various, significant efforts have been made to synthesize evidence in the fields of climate change and migration including the comprehensive collection of resources on the ‘CliMig’ bibliographic database and the knowledge platform ‘Environmental Migration Portal (IOM)’. Our search for these platforms did not reveal comprehensive evidence syntheses using health-related codes. Mcleman and Gemenne (2018) published a comprehensive report synthesizing the evidence on climate change and migration. Additionally, Piguet *et al* (2018) conducted detailed research mapping in the field of environmentally induced migration, presenting an overview of nearly 50 years of case studies yet, without particular attention to health. In terms of climate change and health evidence synthesis, the Intergovernmental Panel on Climate Change (IPCC) Assessment Report 5 (AR5) (2014), is arguably the most comprehensive literature synthesis and assessment, examining climate and health as well as climate and migration but not climate-migration-health simultaneously. Finally, migration was not included in the most recent Lancet Countdown on Health and Climate Change (Watts *et al* 2019).

It is thus timely to examine the literature that has emerged since the 1990 s, exploring the connections between climatic changes, human migration, and population health. This assessment will be of significance given the high levels of climate-related migration anticipated in the future (RigAud *et al* 2018), and the limited consideration to date of specific aspects of the adaptive potential of climate-change-related migration, especially in terms of health.

Four conceptual frameworks were used to develop this assessment to build on existing theories, add depth, and to involve the key disciplines involved in this research area. They include; (i) the IPCC risk diagram adapted to include the human experience of environmental change as a driver of migration and its potential impacts on health (Schwerdtle *et al* 2018); (ii) the three-pronged nexus highlighting linkages between climate change, migration and health dimensions in the context of planetary health (Schütte *et al* 2018) (iii) the relationship of climate change to potential population movements (Mcmichael *et al* 2012) and; (iv) a conceptual model for the drivers of migration (Black *et al* 2011) illustrating that all five macro-drivers of migration (including political, demographic, and economic drivers) are affected by broader environmental change, such as climate change. These are four existing frameworks that this systematic assessment joins together and builds upon using the findings of this meta-synthesis.

This assessment aimed to synthesize the evidence on health and migration in the context of a changing

climate. The PICO (Population—Intervention—Comparator—Outcome) approach to systematic literature reviews is suited to clinical questions using interventional studies. The case of climate change and health research that examines a wide spectrum of temporospatial scales requires a different approach. Research of the tertiary, indirect, socially-mediated impacts of climate change (such as migration and conflict) tends to lead to projections and risk estimates that are qualitative (McMichael 2015, p 51–69 chapter in Levy and Patz, 2015). As qualitative methods do not have an intervention nor comparator, an alternative PICO was required: PEO (Population—Exposure—Outcome). The PEO approach is well suited to population health questions involving observational studies (Pollock and Berge 2018) and research questions aiming to determine the association between exposures, risk factors, and outcomes (Munn *et al* 2018). The population of interest was individuals or communities engaging in or affected by a mobility response; the exposure was a climate hazard, and the outcome was a direct or indirect health outcome. The specific objectives of this systematic assessment were as follows:

- (a) To synthesize empirical evidence about the climate change-migration-health nexus.
- (b) To identify the methodologies and research questions.
- (c) To determine the study settings, populations, mobility responses, and health outcomes.
- (d) To identify knowledge gaps and clusters (aggregated knowledge) in the evidence base.
- (e) To define both positive and negative health impacts of climate-related migration on populations as well as climate impacts on health that drive mobility responses and how relationships between climate-related migration and health relate to circumstances (e.g. vulnerabilities) and interventions (e.g. planned relocation).

2. Methods

The systematic assessment protocol was registered with the international systematic literature review platform Prospero on 29.8.2018 (Registration no: CRD42018095461). Besides a review entitled; ‘Do climate change and health drive human migration?’, no similar protocols have been registered with Prospero since thus our work is unique. This assessment is not considered an evidence map because it is restricted to empirical evidence, excludes grey literature, and uses a quality appraisal process (Bayliss *et al* 2016). Custom systematic literature review software (Covidence ©) was used by independent authors (PNS, IM, CB, CM). In the first stage, two authors voted according to the title and abstract whether the article was eligible. Two votes were required to progress

to the second stage of full-text screening. Inconsistencies between paired screeners in both stages were resolved by an independent third author. The final studies were appraised for quality using the Mixed Method Appraisal Tool (MMAT). The MMAT is a checklist for concomitantly appraising and describing studies included in systematic mixed studies reviews that include both qualitative, quantitative, and mixed methods studies (Hong *et al* 2018). The MMAT was considered better suited than Cochrane tools as authors expected to find a diverse range of quantitative, qualitative, and mixed methods studies (Hong *et al* 2018). Extraction codes were predetermined by reviewers and aligned with the aims and objectives. The codes were deemed most relevant to policy, practice, and further research through a consensus-building process with all authors experienced in the fields of climate change and migration and climate change and health. These codes included; Study setting, research question, study design, climate hazard, other migration drivers, population studied, health outcome, other outcomes, mobility response, the health impact of mobility, the field of research, results/main findings, barriers to migration, key recommendations, and limitations. Due to the heterogeneity of the results, a meta-analysis⁷ was not feasible (even of the quantitative studies because the health outcomes and measurements were diverse) and a meta-synthesis⁸ was conducted using the Collaboration for Environmental Epidemiology methodology (CEE 2018) as well as thematic analysis methodology (Braun and Clarke 2006).

The protocol was developed in consultation with the IOM Migration Environmental and Climate Change Division, and as part of a coordinated effort by Environmental Research Letters to synthesize evidence in preparation for IPCC AR6.

2.1. Definition of terms

For the purposes of this synthesis research, ‘climate change’ was defined as a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC 2018). This assessment included studies exploring climate variability and any climate hazard or extreme weather event that could be plausibly linked to anthropogenic climate change and where authors referred to climatic change. ‘Health’ was defined broadly to include physical, mental, and social components and due to the population health

⁷ Meta-analysis is a statistical method for pooling the results of several studies reporting the same outcome, in order to gain a better estimate of the effect size of an intervention (Cochrane).

⁸ Meta-synthesis is a synthesis of qualitative evidence. We used a meta-aggregative approach to the synthesis that is sensitive to the practicality and usability of the primary author’s findings and does not seek to re-interpret those findings as some other methods of qualitative synthesis do (JBI 2020).

nature of this assessment, was extended to include food security⁹ and water security,¹⁰ and water, sanitation, and hygiene (WaSH). The definition was not extended to the social determinants of health,¹¹ which were examined separately.

Studies were included whether health was considered as a driver or an outcome of climate change-related migration. ‘Migration’ was defined as the movement of persons away from their place of habitual place of residence, either across an international border or within a state regardless of legal status, degree of choice, causes of movement, or length of stay (IOM 2019a). This included all possible mobility responses such as forced displacement, migration, and planned relocation (The Nansen Initiative 2015). The population studied was required to engage in or be affected by a mobility response. This included populations at the origin, mobile, and host communities. Immobility was also considered a mobility response to ensure trapped populations were not excluded. In summary, the assessment did not narrowly focus on the health of ‘climate migrants/climate refugees’ but rather included research that studied health and migration in the context of a changing climate.

This nexus crosses several research fields and intersects with both natural and human sciences, and therefore the evidence originated from diverse disciplines including demography, climatology, public health, policy, international relations, and geography. With this in mind and consultation with a subject librarian the following four academic databases were selected; CABI Direct—Global Health (1973 to present); Ovid Medline (1946 to present); PubMed (1966 to present) and Scopus (1970 to present). Also, Google Scholar was searched with the same search terms. Grey literature was not included in this assessment due to the focus on empirical evidence and a recognition of the multitude of conceptual papers and editorials on this topic. Nevertheless, the search strategy was designed to capture primary studies included in important grey literature reports.

The RepORting Standards for Systematic Evidence Syntheses (RoSES) Pro-forma and flow diagram was used as the quality criteria framework for

reporting because it was specifically created for environmental management and conservation research (Haddaway *et al* 2017) which integrates diverse methodologies.

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Moher *et al* 2009) was not appropriate due to its focus on clinical trials and emphasis on meta-analysis.

2.2. Search strategy

Types of studies: All research designs that included empirical data whether primary or secondary, were considered for inclusion. Due to methodological ambiguity in the search results, the ‘empirical’ criterion was further refined to require a methodological explanation and a description of the data used. Modeling and qualitative case studies were included but commentary, editorials, and literature reviews were not.

Search Terms: Table 1 outlines the search terms which were categorized using the PEO approach (modified PICO) under three concepts and the search was conducted across (AND) and down (OR) with synonyms for the key search terms: Climate Change, Health, and Migration. The search strategy consisted of free-text and MeSH (i.e. Medical Subject Headings) terms and was tailored to the search requirements of each database (figure 1: Example search string Scopus). Several preliminary pilot searches were conducted from September—November 2018 to test the search strategy. Test searches revealed very few publications on the topic before 1990. The chosen timeframe was thought to capture the most current and relevant evidence about the research aims and specific objectives. Test searches also revealed a multitude of studies examining plant and animal health and migration in the context of climate change and led to a reconsideration of the selected databases. The actual search was conducted in December 2018 and was limited to studies published in English or German.

2.3. Inclusion and exclusion criteria

Table 2 outlines the inclusion and exclusion criteria, which were strictly applied to each study. The assessment included research investigating populations worldwide engaging in or affected by mobility responses. These responses were on a spectrum from displacement, encompassing forced movements, to migration, which is considered predominantly voluntary, and also immobility. Populations from places of origin as well as mobile and host populations were included. The assessment required a climate hazard as at least one driver of the mobility response. If a migration driver was economic, political, social, and/or demographic and there was no explicit or implied link to climate change or climate variability the article was excluded. If the hazard was not related to climate change (e.g. volcano, earthquake) the article was

⁹ Food security: Exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life (FAO 2020).

¹⁰ Water security: The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (United Nations 2013).

¹¹ The social, economic, and environmental, political and cultural factors that influence health outcomes. Examples; Employment, Early Life, Income, Education, Housing (Wilkinson and Marmot 2003).

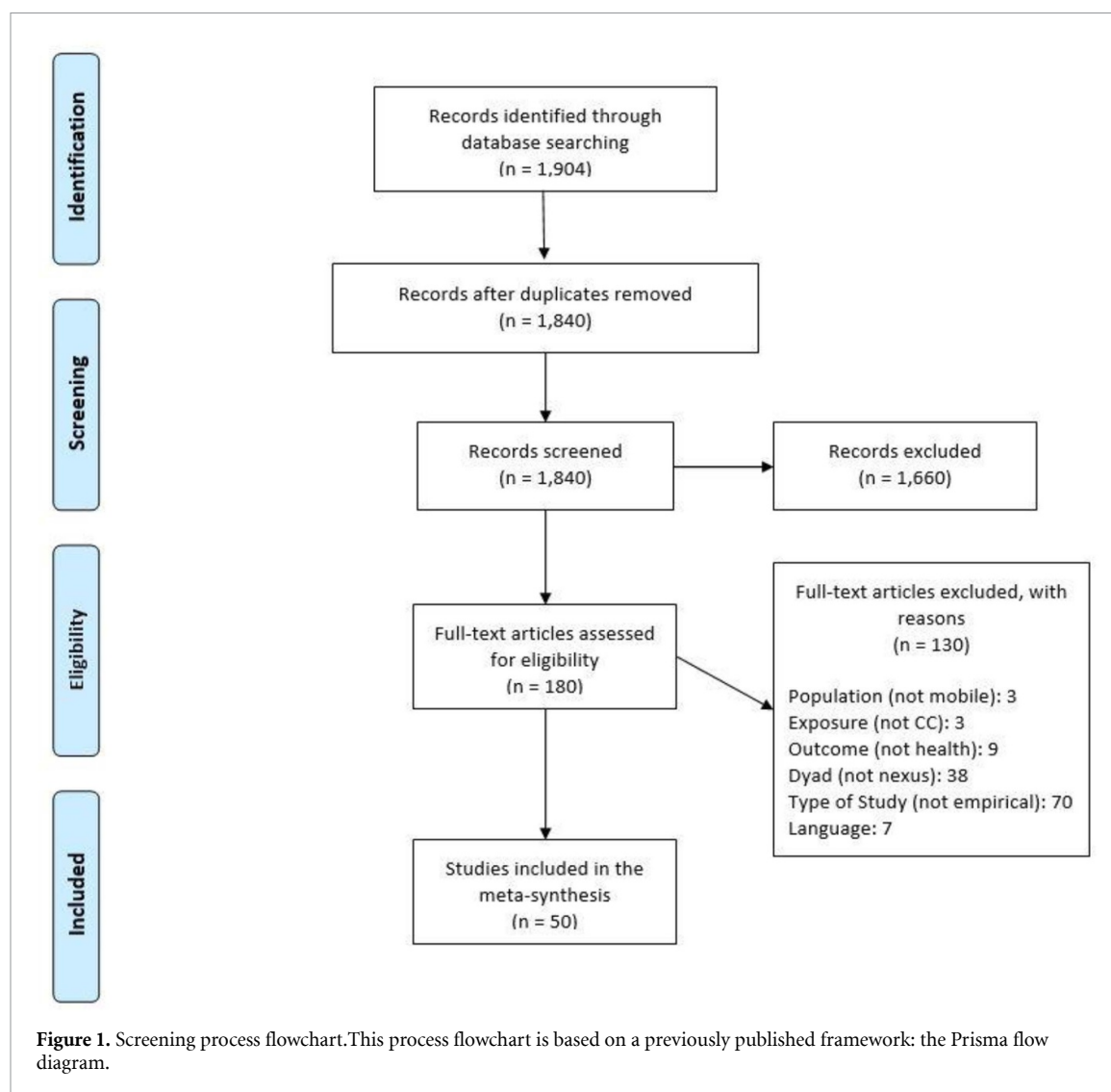


Table 1. Search terms.

Concept 1: Migration (Population)	Concept 2: Climate Change (Exposure)	Concept 3: Health (Outcome)
Population movement	Climate variability	Well being
Population displacement	Global Warming	Disease: NCD, Communicable, Infectious
Forced displacement	Weather Variability	Epidemiolog*
Internal displacement	Greenhouse Effect	Lifestyle
Seasonal migration	Sea Level Rise	Co-benefits
Permanent migration	Environmental disaster	Mortality
Planned relocation	Drought	Morbidity
Migrant	Climate Hazard	Climate sensitive disease*
Mobility		
Internally Displaced Persons Refugee		Nutrition: Malnutrition, Undernutrition Mental disorders: Mental Health, Psychosocial Dehydration Health Services: Health Care Services Health determining sectors: Water and Sanitation, Food Security

*truncated term

excluded. The assessment required studies to focus on health including measurable health outcomes (e.g. prevalence of disease) or immediate determinants of health considered by this assessment to be food and water security. Studies that referred to social

determinants of health as outcomes (e.g. income, employment) were excluded.

Authors were not able to make unilateral decisions to include their own work because each study was reviewed by at least two independent

Table 2. Inclusion and exclusion criteria.

Criterion	Inclusion	Exclusion
Population	Engaging in or affected by a human mobility response. Any country, any population size (village, community, nation, region).	No human mobility response. Mobility of plant or animal.
Exposure	Climate change or climate variability as an environmental factor influencing mobility responses. Environmental hazard related to climate change or variability.	Other migration driver (e.g. political, economic, social, demographic) with no reference to environmental change, climate change or climate variability. Environmental hazard not related to climate change or variability (e.g. earthquake, volcano).
Outcome	Health related: either a direct measure of health or health outcome (i.e. disease prevalence) or an indirect measure of health (e.g. food security and WaSH). Access to healthcare services included.	No health outcome. Not human health: animal or plant. Social determinant of health: e.g. livelihood, income, employment, education.
Nexus	Includes climate change, migration and health.	Focus on two elements (dyad) of the nexus (i.e. climate- health; climate-migration) Focus on OneHealth, Planetary Health, Environmental health, but not climate-related health
Study Type	Peer reviewed empirical research. All designs; Quantitative research, Qualitative research including case studies, Mixed Methods, Modelling studies.	Not empirical Systematic reviews Viewpoints/Editorials Book Chapters Grey literature: dissertations, conference proceedings, report.
Time	1990–2018 (December)	Outside this timeframe
Language	Full text available in English or German	Other languages

Table 3. Level of meteorological and climate data integration into selected studies.

Degree of integration of meteorological/climate data	Description	Study count (no. studies taking this approach) n: 50
Level 1: Narrative	Study referred to weather and climate change in the narrative, and/or the environmental event/change can be linked to climate impacts (e.g. hurricane, rainfall variability), but did not display any meteorological data	33
Level 2: Parallel	Study extracted meteorological data and conducted their own analyses describing weather (short time period, or point in time) or climate information independent of migration or health data (data overall several years and aggregated)	12
Level 3: Overlay	Study extracted own meteorological data and overlaid and analysed climate data (for example, as a comparison between drought vs. non-drought years) with migration and/or health data	5

reviewers. This process was also blinded using the Covidence platform so that 'votes' to include or exclude could not be seen by the partner reviewer.

Reference lists of included and excluded studies were scanned for relevant studies that were manually added to the Covidence platform for full-text review to reduce the likelihood that eligible studies were missed. Figure 2 presents the screening process and the key reasons for exclusion.

2.4. Data extraction

Data extraction codes were predetermined and agreed upon by reviewers who have expertise in climate change and migration and climate change and health. Codes were aligned to the aim and specific objectives.

The data were extracted in an excel sheet (supplementary material (available online at stacks.iop.org/ERL/15/103006/mmedia)). Two authors (PNS, IM) reviewed all 50 selected studies in full-text and conducted a quality appraisal and data extraction simultaneously and collaboratively. When consensus could not be reached regarding quality appraisal or extraction coding, a third independent author (CM, KB) was consulted. When data were incomplete, unclear, or missing, an attempt was made to contact the authors of eligible studies.

2.5. Quality appraisal using the mixed methods appraisal tool (MMAT)

The quality appraisal tool MMAT version 2018 was chosen *a priori* and used to identify threats to internal and external validity for all eligible studies. MMAT provides five custom questions for each study design (qualitative, quantitative randomized controlled trials, quantitative non-randomized, quantitative descriptive, and mixed methods), pertaining to both study and reporting quality (Hong *et al* 2018). Quality appraisal results were recorded in the results spreadsheet along with all other coded findings. Three modeling studies could not be appraised by the MMAT and this remains a limitation of this systematic assessment.

2.6. Data analysis & meta-synthesis

All eligible studies were included in the analysis. A meta-synthesis was undertaken which is considered advantageous when dealing with broader research questions with disparate outcomes (CEE 2018). Extracted data were synthesized using Collaboration for Environmental Evidence (CEE) methodology (CEE 2018). More specifically, once data was extracted from the selected papers according to predefined codes, an appropriate analysis method was selected. This consisted of simple descriptive statistics (example for the codes: 'research setting', 'study design') and thematic analysis in the case of more detailed narrative data (example for the codes: 'research question', 'key findings'). In the latter case, we used the six steps outlined by Braun and Clarke

(2006) namely, 1. Familiarizing yourself with your data 2. Generating initial codes 3. Searching for themes 4. Reviewing themes 5. Defining and naming themes 6. Producing the report which included meaningful data presentation and visualization. The quality of the included studies was considered a result and therefore was a component of the meta-synthesis.

3. Findings

3.1. Included studies

The search strategy revealed 1904 studies with 64 duplicates that were removed. We screened 1840 studies by title and abstract and excluded a further 1660 because they did not meet the inclusion criteria or met an exclusion criterion. The main reasons for exclusion at 'first pass' (title and abstract) were: Not empirical evidence (e.g. editorial); Focus on a dyad (either climate change and health or climate change and migration) not the nexus (climate change-health-migration); Animal or plant health/migration not human health/migration. The resultant 180 studies were screened in full-text and 130 were excluded for the reasons outlined in the screening process flow-chart (figure 2). The assessment yielded a total of 50 eligible studies. The main reasons for exclusion at 'second pass' (full-text) screening stage were: Not empirical evidence (e.g. editorial), focus on a dyad (two concepts) not the nexus (all three concepts); no health outcome. Less common reasons included; Mobility driver that was unrelated to climate change, or a population that was not engaged in or affected by mobility.

3.2. Study setting

The 50 eligible studies were conducted in 27 countries. If one study included more than one country, it was duplicated in the analysis so that there were 59 study sites altogether. Figure 3 presents the geographic location of the identified studies by WHO region. Most studies were conducted in the South East Asian region ($n = 21$) followed by the African region ($n = 18$), the Pan American region ($n = 13$) the Western Pacific region ($n = 4$), the Eastern Mediterranean region ($n = 2$) and Europe ($n = 1$). Notably, just under one-quarter of the eligible studies took place in Bangladesh ($n = 12$). 85% of the study settings were in the Global South. Studies were conducted between 1992 and 2018 with the majority covering the period between 2013 and 2016 ($n = 29$). Details about the eligible studies can be found in table 4.

3.3. Research aims of included studies

The assessment revealed a diverse range of research questions, aims, objectives, and hypotheses. The assessment authors characterized these aims using a common research framework in climate change and health that is also used by working groups 2

Table 4. Overview of included studies.

Study no.	Author(s)	Title	Journal	Research setting	Mobility response	Climate hazard(s) experienced	Health outcome(s)	Quality appraisal
1	Abah and Petja (2016)	Assessment of potential impacts of climate change on agricultural development in the Lower Benue River Basin	Environmental Monitoring & Assessment	Nigeria & Cameroon	Rural—Urban migration	Rainfall & temperature variability, floods & droughts, heat stress, surface water trends	Infectious diseases, HIV/AIDS	N/A
2	Adams (2016)	Why populations persist: mobility, place attachment and climate change	Population & Environment	Peru	Trapped populations/immobility	Temperature extremes, excessive precipitation, abrupt seasonal weather changes & drought, glacial retreat	Food insecurity, diseases of animals & humans, burns & headaches, water availability	***
3	Afifi <i>et al</i> (2014)	Rainfall-induced crop failure, food insecurity and out-migration in Same-Kilimanjaro, Tanzania	Climate & Development	Tanzania	Seasonal migration (<6 months) & temporal migration (>6 months)	Rainfall variability, floods & droughts, water shortages	Food insecurity	**
4	Albert <i>et al</i> (2018)	Heading for the hills: climate-driven community relocations in the Solomon Islands and Alaska provide insight for a 1.5 °C future	Regional Environmental Change	Solomon Islands & Alaska	Relocation: Supported and Unsupported.	Sea level rise, reduced Arctic sea ice, melting permafrost, sea-level rise, erosion water borne disease, vector borne disease, dietary adaptation	Access to health care facilities, health & safety risks, water borne disease, vector borne disease, dietary adaptation	****
5	Amstislavski <i>et al</i> (2013)	Effects of increase in temperature and open water on transmigration and access to health care by the Nenets reindeer herders in northern Russia	International Journal of Circumpolar Health	Northern Russia	Inhibition (delaying) regular transmigration	Temperature increase, reduction of ice-rich permafrost & glaciers, changes in hydrological cycles	Access to health care facilities, risks of injury	***
6	Anastario <i>et al</i> (2009)	Increased Gender-based Violence Among Women Internally Displaced in Mississippi 2 Years Post-Hurricane Katrina	Disaster Medicine and Public Health Preparedness	Mississippi, USA	Forced displacement	Hurricane	Sexual & physical violence, suicidal ideation & attempts, depression	****
7	Anupama <i>et al</i> (2016)	Seasonal Migration and Moving Out of Poverty in Rural India: Insights from Statistical Analysis	Asian Journal of Agriculture and Development	Rural India	Temporary/seasonal migration	Drought	HIV/AIDS, water-borne disease, general & sexual health, social issues	**
8	Assan <i>et al</i> (2009)	Environmental variability and vulnerable livelihoods: Minimising risks and optimising opportunities for poverty alleviation	Journal of International Development	North Eastern Ghana	Temporary migration, circular migration	Erratic and declining mean rainfall	Food insecurity	***
9	Atta <i>et al</i> (2013)	Psychological Effects among Internally Displaced Persons (IDPS) residing in two districts of Sindh	Medical Forum Monthly	Sindh, Pakistan	Forced displacement	Flood	Mental disorders	*

Table 4. (Continued).

Study no.	Author(s)	Title	Journal	Research setting	Mobility response	Climate hazard(s) experienced	Health outcome(s)	Quality appraisal
10	Behr and Diaz (2013)	Disparate Health Implications Stemming From the Propensity of Elderly and Medically Fragile Populations to Shelter in Place During Severe Storm Events	Journal of Public Health Management and Practice	North Carolina, USA	Forced displacement, immobility	Hurricane	Access to the support system, medical records, medical regimens, nutrition	**
11	Chen <i>et al</i> (2011)	Risk factors for PTSD after Typhoon Morakot among elderly people in Taiwanese aboriginal communities	International Psychogeriatrics	Taiwan	Relocation	Typhoon	PTSD, injury/death, self perceived health	*****
12	Coker <i>et al</i> (2006)	Social and Mental Health Needs Assessment of Katrina Evacuees	Disaster Management & Response	Houston, USA	Forced displacement/evacuation	Hurricane	NCDs, PTSD	**
13	Craven (2015)	Migration-affected change and vulnerability in rural Vanuatu: Migration-affected change in rural Vanuatu	Asia Pacific Viewpoint	Vanuatu	Seasonal migration	Rainfall variability	Health financing, food security	***
14	Dinkelmann (2017)	Long-Run Health Repercussions of Drought Shocks: Evidence from South African Homelands	The Economic Journal	South Africa	Multiple types of migration, internal migration, labour migration	Drought	Disability (visual, hearing, speech, mental, physical)	***
15	Edwards (2013)	The Logistics of Climate-Induced Resettlement: Lessons from the Carteret Islands, Papua New Guinea	Refugee Survey Quarterly	Carteret Islands, PNG	Forced displacement, relocation	Sea-level rise, King tides, storm surge, floods	Food insecurity, mental health	*
16	Etzold <i>et al</i> (2014)	Clouds gather in the sky, but no rain falls. Vulnerability to rainfall variability and food insecurity in Northern Bangladesh and its effects on migration	Climate and Development	Northern Bangladesh	Labour migration (permanent, seasonal, temporary), immobility	Rainfall variability	Food insecurity	*
17	Gautam (2017)	Seasonal Migration and Livelihood Resilience in the Face of Climate Change in Nepal	Mountain Research and Development	Nepal	Seasonal migration, labour migration	Drought, rainfall variability	Food insecurity	****
18	Grawert (1992)	Impacts of male outmigration on women: A case study of Kutum/Northern Darfur/Sudan	The Ahfad Journal	Western Sudan	Out-migration	Drought	Food insecurity	*

Table 4. (Continued).

Study no.	Author(s)	Title	Journal	Research setting	Mobility response	Climate hazard(s) experienced	Health outcome(s)	Quality appraisal
19	Grecequet <i>et al</i> (2017)	Climate Vulnerability and Human Migration in Global Perspective	Sustainability	Global	Multiple types of migration	Multiple climate-hazards	Mortality from climate-sensitive diseases, vector-borne disease, health (together with food, water, ecosystem services, human habitat, and infrastructure)	N/A
20	Heaney and Winter (2016)	Climate-driven migration: an exploratory case study of Maasai health perceptions and help-seeking behaviour	International Journal of Public Health	Tanzania	Rural—urban migration	Drought	Help seeking behaviour, health care utilisation, food insecurity, water insecurity	****
21	Hori and Schafer (2010)	Social costs of displacement in Louisiana after Hurricanes Katrina and Rita	Population and Environment	Louisiana, USA	Forced Displacement/e-vacuation	Hurricane	Access to primary health care	***
22	Hunter and Simon (2017)	Might climate change the 'healthy migrant' effect?	Global Environmental Change	Mexico & USA	International migration	Rainfall variability	Self-assessed health, adult height (early life nutritional & health conditions)	**
23	Hutton and Haque (2003)	Patterns of Coping and Adaptation Among Erosion-Induced Displacees in Bangladesh: Implications for Hazard Analysis and Mitigation	Natural Hazards	Bangladesh	Forced displacement	Riverbank erosion	Psychological distress	*
24	Iqbal <i>et al</i> (2018)	Farmers perceptions of and adaptations to drought in Herat Province, Afghanistan	Journal of Mountain Science	Herat province, Afghanistan	Labour migration	Drought	Food insecurity, malnutrition	****
25	Islam and Hasan (2016)	Climate-induced human displacement: a case study of Cyclone Aila in the south-west coastal region of Bangladesh	Natural Hazards	Bangladesh	Forced displacement	Cyclone Aila	Access to WASH, access to basic health services	*
26	Islam <i>et al</i> (2014)	Migrating to tackle climate variability and change? Insights from coastal fishing communities in Bangladesh	Climatic Change	Bangladesh	From island to mainland (Rural—Urban migration)	Climate variability	Physical fitness, access to WASH	***

Table 4. (Continued).

Study no.	Author(s)	Title	Journal	Research setting	Mobility response	Climate hazard(s) experienced	Health outcome(s)	Quality appraisal
27	Kabir <i>et al</i> (2016)	Climate change and health in Bangladesh: a baseline cross-sectional survey	Global Health Action	Bangladesh	Forced displacement, homelessness	Cyclones, floods, salinity	Infectious diseases, malaria, dengue, pneumonia, diarrhoea, height & weight, access to health care facilities	**
28	Loevinsohn (2015)	The 2001–03 Famine and the Dynamics of HIV in Malawi: A Natural Experiment	PLOS ONE	Malawi	Rural—urban migration	Climate change and variability	HIV	****
29	Mcelfish <i>et al</i> (2016)	Social Ecology and Diabetes Self-Management among Pacific Islanders in Arkansas	Journal of Family Medicine and Disease Prevention	Arkansas, USA	Migration to the hosting community	Climate change	Type 2 diabetes (language, translation, treatment, diabetes self-management)	****
30	Mertz <i>et al</i> (2009)	Farmers' Perceptions of Climate Change and Agricultural Adaptation Strategies in Rural Sahel	Environmental Management	Senegal (savanna)	Migration	Climate variability (wind, rain, dust storms)	Health, reduced solidarity	****
31	Messias <i>et al</i> (2007)	Katrina-Related Health Concerns of Latino Survivors and Evacuees	Journal of Health Care for the Poor and Underserved	Louisiana, Mississippi & Georgia, USA	Evacuation	Hurricane Katrina	Hunger, environmental health risks, sleep disturbances, access to health care	****
32	Milan and Ruano (2014)	Rainfall variability, food insecurity and migration in Cabricán, Guatemala	Climate and Development	Guatemala	Seasonal & permanent migration	Rainfall variability	Food security (threat of local livelihoods)	****
33	Molla <i>et al</i> (2014a)	Quantifying disease burden among climate refugees using multidisciplinary approach: A case of Dhaka, Bangladesh	Urban Climate	Dhaka, Bangladesh	Migration, refugees	Flood/river erosion, drought	DALYs lost, diarrhoea, asthma, morbidity	****
34	Molla <i>et al</i> (2014b)	Multidisciplinary household environmental factors: Influence on DALYs lost in climate refugees community	Environmental Development	Dhaka, Bangladesh	Migration	Flood/river erosion, drought	DALYs lost, diarrhoea, asthma	**
35	Murali and Afifi (2014)	Rainfall variability, food security and human mobility in the Janjigir-Chhattisgarh district of Chhattisgarh state, India	Climate and Development	Chhattisgarh state, India	Seasonal & permanent migration	Rainfall variability	Food insecurity, living quality in the city	****
36	Hutton and Haque (2004)	Human Vulnerability, Dislocation and Resettlement: Adaptation Processes of River-bank Erosion-induced Displacees in Bangladesh	Disasters	Bangladesh	Involuntary migration, erosion-induced displacement, rural-urban migration	Flooding/river-bank erosion	Health problems, household hunger	**

Table 4. (Continued).

Study no.	Author(s)	Title	Journal	Research setting	Mobility response	Climate hazard(s) experienced	Health outcome(s)	Quality appraisal
37	Nawrotzki <i>et al</i> (2016)	Climate, migration, and the local food security context: introducing Terra Populus	Population and Environment	Burkina Faso & Senegal	International migration	Adverse climate changes (heat waves, droughts, floods)	Food security, child (<5 yrs) stunting & wasting	*****
38	Oyekale <i>et al</i> (2013)	Impacts of flooding on coastal fishing folks and risk adaptation behaviours in Epe, Lagos State	African Journal of Agricultural Research	Nigeria	Migration	Flooding	Malaria, typhoid, cholera, diarrhoea, dysentery, influenza, tuberculosis	**
39	Penning-Rowsell <i>et al</i> (2013)	The 'last resort'? Population movement in response to climate-related hazards in Bangladesh	Environmental Science & Policy	Bangladesh	Temporary evacuation	Hazard events & disasters	Ill-health, lack of space & hygiene	***
40	Perez-Saez <i>et al</i> (2017)	Climate-driven endemic cholera is modulated by human mobility in a megacity	Advances in Water Resources	Dhaka, Bangladesh	Urban migration	El Nino Southern Oscillation (ENSO)	Cholera	N/A
41	Philibert <i>et al</i> (2013)	Birth seasonality as a response to a changing rural environment (Kaves Region, Mali)	Journal of Biosocial Science	Mali	Seasonal migration	Climate & rainfall	Births registered in primary health care facilities	****
42	Rademacher-Schulz <i>et al</i> (2014)	Time matters: shifting seasonal migration in Northern Ghana in response to rainfall variability and food insecurity	Climate and Development	Northern Ghana	Seasonal & labour migration	Rainfall variability	Livelihood, food security	*
43	Rahaman <i>et al</i> (2018)	Health Disorder of Climate Migrants in Khulna City: An Urban Slum Perspective	International Migration	Khulna City, Bangladesh	Slum migration	Climatic disasters (flooding, cyclone, storm surges, sea level rise, river erosion)	Waterborne diseases, under-nutrition, micronutrient deficiencies, diarrhoea, malaria	**
44	Roncoli <i>et al</i> (2001)	The costs and risks of coping with drought: livelihood impacts and farmers' responses in Burkina Faso	Climate Research	Burkina Faso	Migration (sending of relatives)	Scarce and irregular rainfall, infertile and degraded soils, drought	Livelihood, food security	**
45	Shanthi <i>et al</i> (2017)	Assessment of challenges faced by the coastal women due to the impact of climatic change in selected coastal districts of Tamil Nadu, India	Indian Journal of Fisheries	Tamil Nadu, India	Urban migration	Unusual rainfall, floods, cyclones, change in water quality	Livelihood, health	***

Table 4. (Continued).

Study no.	Author(s)	Title	Journal	Research setting	Mobility response	Climate hazard(s) experienced	Health outcome(s)	Quality appraisal
46	Suckall <i>et al</i> (2017)	Reduced migration under climate change: evidence from Malawi using an aspirations and capabilities framework	Climate and Development	Malawi	Internal migration	Climate stresses (droughts) and shocks (sudden flooding)	Food shortage	*
47	Tschakert <i>et al</i> (2013)	Embodied experiences of environmental and climatic changes in landscapes of everyday life in Ghana	Emotion, Space and Society	Ghana	Rural—urban migration	Environmental and climatic change (unpredictable and shifting rainfall)	Well-being, distress	****
48	van der Geest <i>et al</i> (2014)	Internal migration in the upper mekong delta, viet nam: what is the role of climate related stressors?	Asia-Pacific Population Journal	Vietnam	Internal migration	Climate-related stressors (floods, storms, rainfall)	Food insecurity	***
49	Warner and Afifi (2014)	Where the rain falls: Evidence from 8 countries on how vulnerable households use migration to manage the risk of rainfall variability and food insecurity	Climate and Development	Guatemala, Peru, Ghana, Tanzania, Bangladesh, India, Thailand & Vietnam	Migration	Rainfall variability	Food insecurity (food production & market food availability)	****
50	Wolsko and Marino (2016)	Disasters, migrations, and the unintended consequences of urbanization: What's the harm in getting out of harm's way?	Population and Environment	Shishmaref, Alaska	Planned relocation	Erosion, wind, ice melt, floods	Mental health status	**

Individual Quality Appraisal. The ranking system is according to the articles adherence to each of the criteria i.e.—frequency (%) we could answer 'yes' to the quality appraisal question and not 'no' or 'cannot tell' (****=100%, ***=80%, **=60%, *=40%, * = <20%). In mixed methods studies, there were 15 quality appraisal (QA) questions (quantitative component, qualitative component, qualitative component, qualitative component, mixed methods general) and we used the overall score (denominator: 15 not 5) (See supplementary material 2 a).

QA Collated by method. When we refer to quality appraisal overall being 'high' in the text, we refer to the frequency (%) with which we could answer 'yes' to the QA questions for that method group i.e. Qualitative or Quantitative Non-Randomised where: Very high (81%–100%) High (61%–80%) Good (41%–60%) Fair (21%–40%) Poor (0%–20%) (See supplementary material 2 (b)).

"climate change" OR "climate variability" OR "global warming" OR "weather variability" OR "greenhouse effect" OR "disaster" OR "extreme weather" OR "sea level rise" OR "environmental disaster" OR "drought" OR "climate hazard"

"health" OR "well being" OR "disease" OR "non-communicable" OR "NCD" OR "Communicable" OR "Infectious" OR "epidemiolog*" OR "lifestyle" OR "cobenefits" OR "mortality" OR "morbidity" OR "climate sensitive" OR "nutrition" OR "malnutrition" OR "undernutrition" OR "dehydration" OR "mental disorders" OR "mental health" OR "psychosocial" OR "health services" OR "healthcare" OR "health determining sectors" OR "water sanitation" OR "food security"

"migration" OR "population movement" OR "population displacement" OR "forced displacement" OR "internal displacement" OR "seasonal migration" OR "permanent migration" OR "planned relocation" OR "migrant" OR "internally displaced person" OR "refugee" OR "internal migration" OR "mobility" OR "environmental refugee" OR "environmental migrant"

Figure 2. Example search string Scopus.

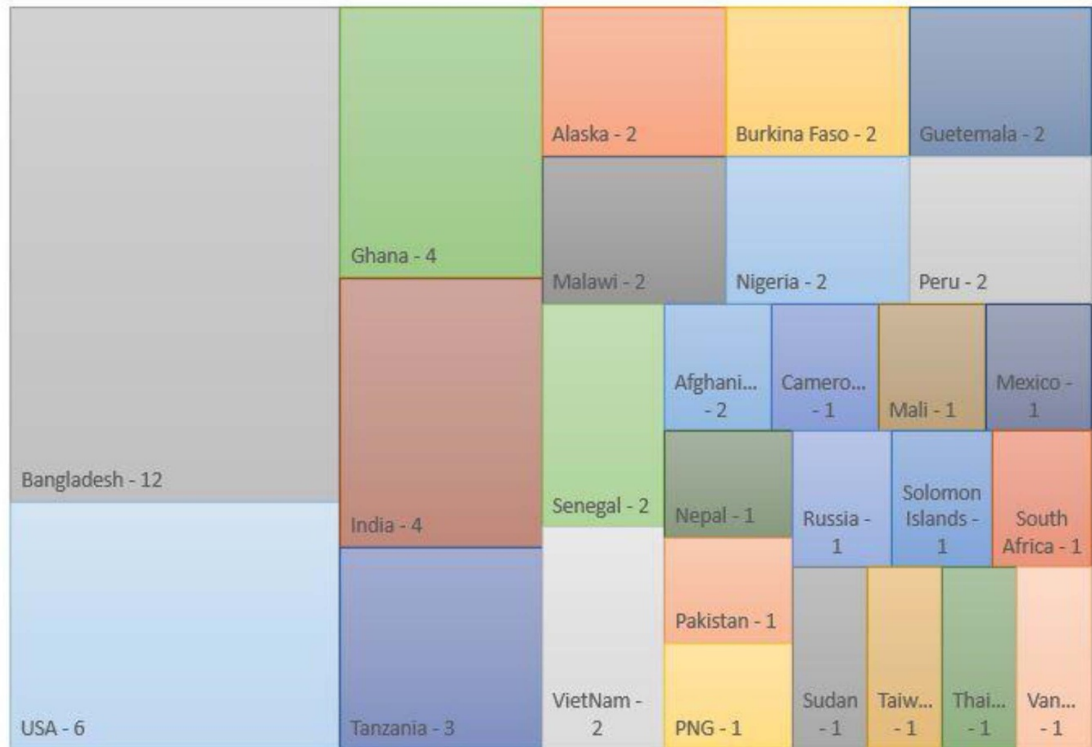


Figure 3. Study settings (Afghani: Afghanistan, Camero: Cameroon, PNG: Papua New Guinea, Taiw: Taiwan, Thai: Thailand, Van: Vanuatu).

and 3 of the IPCC; (1) Health impacts of climate change; (2) Adaptation to climate change for health including the health (and other) co-benefits of mitigation (IPCC 2014). Studies looking at the health impacts of climate-related migration asked the broad question: What are the relationships between migration and health in the context of climate change? (See table 4 studies: 3, 5, 6, 7, 10, 16, 20, 21, 27, 37, 41, 47). Others measured health outcomes in

climate-displaced communities (table 4 studies: 9, 11, 12, 14, 25, 28, 29, 33, 34, 40, 43). Of course, not all research aims fit neatly into these categories and some looked at both ‘impacts’ and ‘adaptation’ (table 4 studies: 35, 38). Others were quite different and explored the association between climate vulnerability scores and net migration (table 4: 19) or how climate change influences the so-called ‘healthy migrant effect’ (table 4: 22).

Studies fitting under the ‘adaptation’ theme aimed to assess perceptions of climate change and implications for mobility with health being a finding (table 4 studies: 2, 8, 17, 24, 30, 32). Others considered the extent to which climate-related mobility was adaptive or maladaptive using health outcomes as an indicator (table 4 studies: 36, 42, 44, 48, 49). A few focused on relocation and explored the barriers and facilitators to success some of which related to health (table 4 studies: 4, 15). No eligible studies looked at the health co-benefits of mitigation in reference to climate-related migration and health.

3.4. Study design

The eligible studies ($n = 50$) were categorized, with reference to MMAT, into five types of study design: quantitative descriptive studies (15; 30%), quantitative non-randomized studies (7; 14%), qualitative case studies (13; 26%), mixed-methods studies (12; 24%); and modeling studies (3; 6%).

3.5. Quality appraisal

Each study was individually appraised for quality using the MMAT tool and we condensed a finding of the overall quality of evidence by methodological group (see table 4 and supplementary material) (Hong *et al* 2018). For individual studies, the quality score was attained by using the five custom questions for each study. We used a ranking system according to the articles’ adherence to each of the criteria i.e.—% time we could answer ‘yes’ to the quality appraisal question (****100%, ***80%, ** 60%, * 40% * = < 20%). In mixed methods studies there were 15 quality appraisal questions (quantitative component, qualitative component, mixed methods general) so 15 rather than 5 was used as the denominator. For the overall rating we also used the % time we could answer ‘yes’ to the quality appraisal questions overall for that particular study design (see explanation below table 4 for more details). Below we present a critical appraisal in narrative form that aims to characterize the nature of the included studies, explore quality issues, and provide an explanation of the key strengths and weaknesses identified.

The eligible quantitative descriptive studies ($n: 15$) mainly consisted of surveys and case reports. These studies aimed to describe the existing distribution of variables without regard to causal relationships and are well suited to generate hypotheses. Of the quantitative descriptive studies two received a rating of *, three received a rating of **, four received a rating of ***, three received a rating of ****, and three received a rating of *****. Overall, the quality was high (63% QA questions answered ‘yes’¹²).

We observed a lack of methodological detail, including sampling strategy, resulting in difficulty determining representativeness and limiting reproducibility. Yet measurements were largely appropriate and the risk of non-response bias was generally low. Analysis ranged from simple descriptive statistics to regression analyses.

The eligible quantitative non-randomized studies ($n: 7$) mainly consisted of cross-sectional analytic studies that were used to study climate exposures without using randomization to allocate units to comparison groups. These types of studies were considered a ‘step up’ methodologically from quantitative descriptive studies as they usually compared migrating and non-migrating households and resultant health outcomes, or climate-vulnerable and less climate vulnerable households. Of the quantitative non-randomized studies three received a rating of **, three received a rating of *** and one received a rating of *****. Overall, the quality was high (63%). Quality issues included temporal-spatial scales of the hazard, mobility response, and health outcomes rarely matching, representing an important methodological limitation. Some studies inadequately matched comparison groups demographic-ally or paid limited attention to confounding.

Eligible qualitative studies ($n: 13$) mainly consisted of case studies and narrative research. These comprised a significant portion of the selected studies even without considering the qualitative component of eligible mixed-method studies. Of the selected studies, qualitative methods were used to explore and explain in-depth the issues intrinsic to a particular case of climate-related migration and health. Of the qualitative studies two received a rating of *, two received a rating of **, two received a rating of ***, two received a rating of **** and five received a rating of *****. Overall, the quality was high (68%). Qualitative studies with higher MMAT scores described data collection in detail and derived findings clearly from the data (e.g. using quotes to substantiate themes). Those with lower MMAT scores did not demonstrate coherence between data sources, collection, analysis, and interpretation.

The included mixed methods studies ($n: 12$) combined quantitative descriptive studies (mostly using surveys) with qualitative methods (mostly using focus groups or interviews). Mixed methods seemed to be well suited to the topic due to its methodological complexity and the fact that one method can complement the other and provide further details and explanations. Stronger versions balanced the emphasis on each method per the research question and adhered to the quality standards for both qualitative and quantitative components. Of the mixed

¹² For the overall QA score by method: Very high (81%–100%) High (61%–80%) Good (41%–60%) Fair (21%–40%) Poor (0%–20%) This refers to the % time assessors could answer ‘yes’ (not

‘no’ or ‘cannot tell’) to QA questions. Further information below table 4 and in supplementary materials.

methods studies, four received a rating of *, two received a rating of **, three received a rating of ***, three received a rating of ****. Overall the quality was high (67%). Mixed methods studies with higher MMAT scores rationalized the approach and the choice of convergent or sequential design. They also meaningfully integrated the data types and identified and addressed divergences and inconsistencies between qualitative and quantitative results. Those with lower MMAT scores superficially applied one method and lacked integration i.e.—quantitative and qualitative results were reported and interpreted separately.

The modeling studies (n: 3) were included as there was no reason to exclude them according to the protocol however, MMAT could not be used to appraise their quality and this remains a limitation of this systematic assessment.

3.6. The relationships between climate hazards, mobility responses, and health

The key concepts of this assessment as defined by the PEO approach (Populations participating in, or affected by mobility responses; the Exposure of climate hazards; and health Outcomes) were coded, extracted, and synthesized into a narrative, tables, and appropriate data visualizations. A conceptual map is shown in figure 4 integrated the results of this assessment into the four conceptual frameworks outlined in the introduction.

Figure 4 shows that climate change impacts are mediated through a range of socio-economic and other factors with different consequences for migration and health and that food and water security play an important role in these complex, multifaceted and interacting pathways. Some of these pathways depicted in figure 4 may be empirically difficult to estimate due to under-representation in the literature.

A Sankey diagram (figure 5) further characterizes the intersections between mobility responses and health in the context of climate change. The graph depicts the evidence captured by this assessment. The mobility responses (left side) are linked with health issues and outcomes investigated in the eligible studies (right side). The width of the flows is proportionate to the number of relevant studies. Multiple connections within a study are depicted with 101 individual connections from 50 included studies. The nature of these relationships is not depicted in the Sankey diagram but was both positive and negative. In other words, certain mobility responses in the context of climate change both benefited and compromised health, yet the predominant relationship was negative in the eligible studies. Predominant patterns of mobility include forced displacement, rural-urban migration, relocation, and seasonal migration. Predominant health outcomes include food insecurity, access to healthcare, infectious disease, and

mental health issues. Forced displacement and relocation was associated with food insecurity, access to healthcare and mental health issues whilst rural-urban migration and seasonal migration was associated with food insecurity, access to health care, and infectious disease. The terminology in the diagram reflects the language used in the research papers and demonstrates numerous connections (see section 4.2).

4. Discussion

This assessment revealed five main findings: (1) there is a paucity of empirical research exploring this nexus, (2) relationships between health and migration in a changing climate are strongly heterogeneous so that overall global findings are unlikely to emerge; (3) health concerns have been researched in the context of climate change and migration including changing patterns of infectious disease, non-communicable disease, psychosocial health issues and access to health care; (4) food and water security act as important mediators of migration responses and health outcomes in the context of a changing climate and (5) climate data are variably integrated into this evidence base. These findings are now discussed in the context of other relevant literature.¹³

4.1. Paucity of empirical research on this nexus

First, within the extensive literature on climate change and health, proportionately few studies explore it concerning migration. Similarly, within the climate change and migration literature, proportionately few studies explore health (n: 50) (figure 2: Screening process flowchart). Within this evidence base there seems to be a transition from attempting to isolate sole drivers of migration and to quantify the number of people likely to be on the move under different climate scenarios, to a more nuanced discussion about how multiple factors interact to shape migration choices. Such research looks at the circumstances under which people move in a changing climate and the consequences for health. It is now important to extend this research further to reveal insights on how human health can be protected and promoted in the context of new patterns of human mobility as the climate crisis accelerates. This is crucial as people who are displaced due to climate change do not have the international protection afforded to refugees, and people internally displaced from climate impacts may fall through the gaps of national protection frameworks.

¹³ The 50 studies included in this assessment are identified with a number in the discussion that aligns with table 4. The author/date system is otherwise used to denote relevant studies (some of which were caught by the search but later excluded in the screening process) that are useful for putting the findings in the context of existing literature.

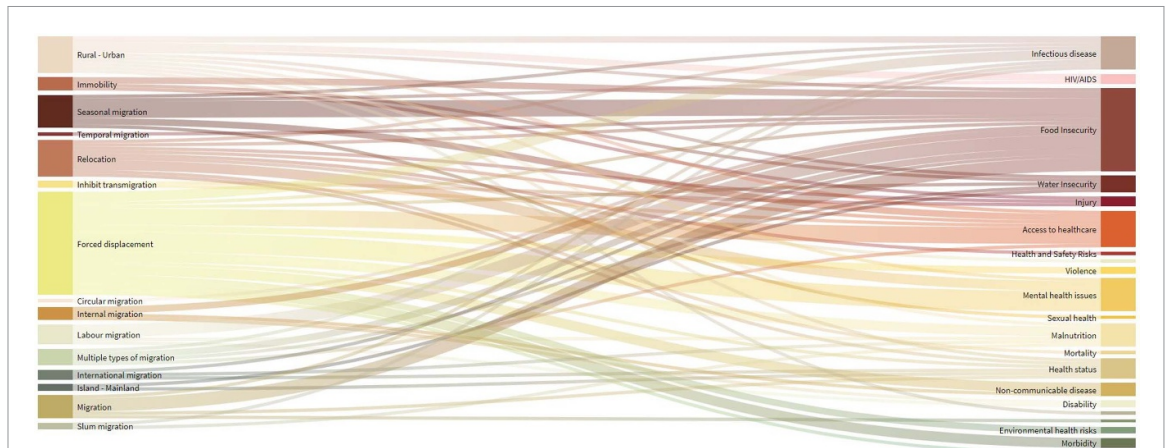


Figure 4. Sankey diagram the relationships between mobility and health in the context of a changing climate.

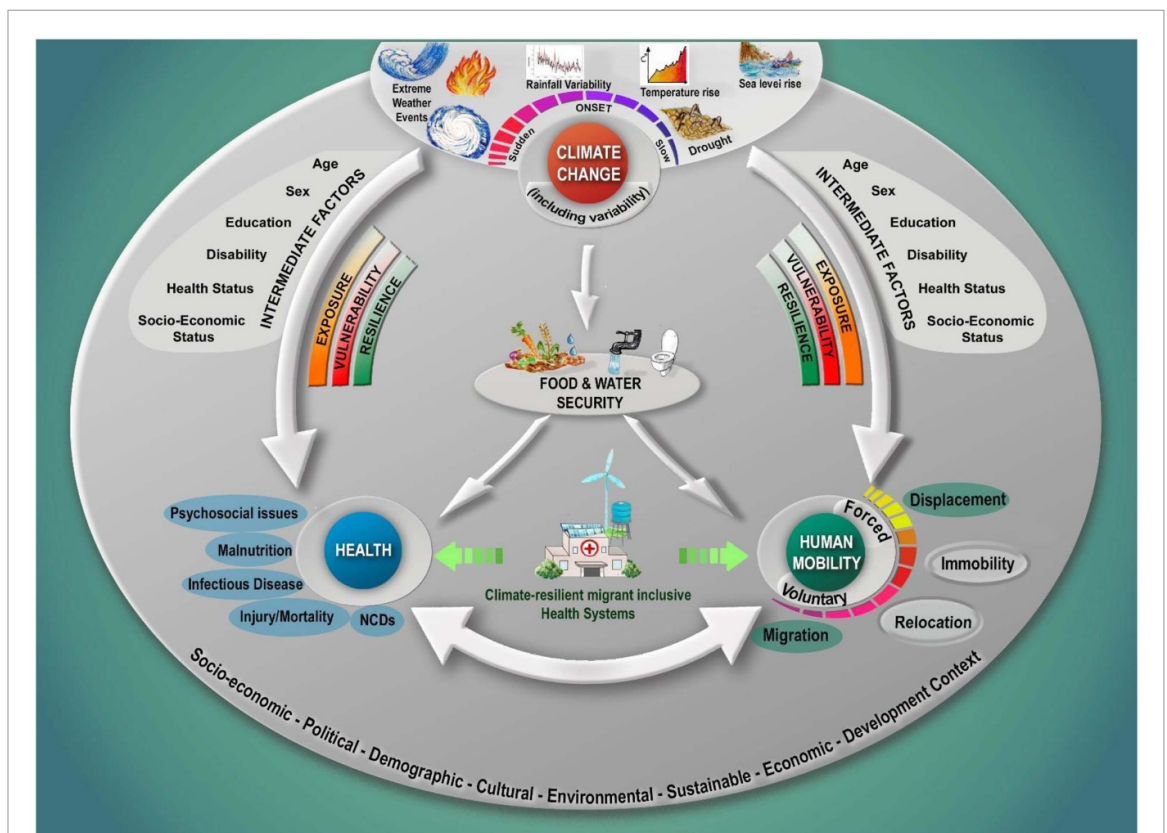


Figure 5. Human mobility and health in the context of changing climate: a conceptual map. Systematic literature assessment findings integrated with four existing conceptual frameworks with overlapping concepts. Uni-directional arrow depict a one way relationship whilst bi-directional arrows depict a two way relationship.

Considering that migration frameworks encourage ‘whole of government approaches ¹⁴’ (Abubakar et al 2018, IOM 2019b) and climate change and health frameworks rely on inter-sectoral collaboration (IPCC 2014, WHO 2016), the research community will need to keep pace by adopting systems thinking to explore this type of nexus research

and provide policy-relevant insights. As a minimum, climate change and health can be incorporated into migration research, and migration considered a determinant of health, as well as an important consideration within climate change adaptation frameworks.

4.2. Pathways between climate change-related migration and health are strongly heterogeneous Second, relationships between climate change, migration, and health are strongly heterogeneous. These

¹⁴ ‘Whole-of-Government Approach (‘WGA’) the joint activities performed by diverse Ministries, Public Agencies and Public Administrations in order to provide a common solution to a problem (IOM 2020).

relationships appear to depend on the differential exposure, sensitivity, vulnerability, and adaptive capacity of populations and are mediated by several social, economic, political, and demographic factors. Consequently, as the conceptual map demonstrates (figure 4), it is difficult to form general conclusions about how these relationships work, especially under variable climate scenarios, potential mitigation, and adaptation activities, and climate and social tipping points.

Since there is no definitive relationship between climate change, migration, and health, each case must be carefully assessed, taking health and the determinants of health into account and recognizing that migration is not uniformly an adaptive solution to climate change risk (Warner and Afifi 2014, Adams 2016, IOM 2020).

In recognition that mobility responses to climate change can (to different degrees) be adaptive or maladaptive in terms of health and other dimensions, approaches are required to address the vulnerabilities of communities at risk of (and engaged in) forced migration and to support people engaged in and affected by mobility as a form of adaptation to climate impacts. This heterogeneity may require policy and practice to be broad and responsive enough for the context of rapid change and uncertainty so that narrow views about what the future may bring do not cause further harm or reduce the range of adaptive possibilities (Mertz *et al* 2009, Philibert *et al* 2013).

The heterogeneity in the literature essentially means that there are strict limits on what can be synthesized. There is a need to further develop evidence-synthesis methodologies that can better deal with diverse bodies of evidence, especially in light of growing transdisciplinary research. Accordingly, the policy implications of this assessment need to be cautiously interpreted with these limitations in mind. In sum, we interpret the evidence to indicate that policy and action should be responsive enough to protect health—and health determinants, especially food and water security—regardless of the climate scenario. Such policies may include those which protect the human rights of migrants, ensure food and livelihood security, support sustainable agriculture, and mobilize remittances to benefit health (table 4: 3, 4, 15, 17, 24, 28, 34, 44; IOM 2020).

The heterogeneity inherent in the current evidence base means that climate hazards can both increase and restrict mobility (Behr and Diaz 2013, Etzold *et al* 2014, Adams 2016), and that mobility responses can both benefit and compromise health. The included studies indicate that climate hazards can impact areas within a country differently, as well as communities within a region, households within a community, and even individuals within a household. Yet this complexity must not lead to inaction. This finding should rather prompt researchers, practitioners, and policymakers to acknowledge how

multiple drivers of migration interact with climate hazards to contribute to causal chains leading to different mobility patterns (Future Earth 2019), and to seek to protect and promote the health of affected populations.

4.3. Health issues researched in the context of climate change and migration

The third finding of this assessment reveals that health can be a precursor, driver, or outcome of migration. For example, climate change-related health threats can act as mobility drivers as people seek to move to sites of reduced risk and/or in hope of better health and livelihood (Islam *et al* 2014, van der Geest *et al* 2014, Mcelfish *et al* 2016, Grecequet *et al* 2017).

Alternatively, health risks and diminished mental well-being can emerge among migrant populations en-route and in destination sites (Tschakert *et al* 2013, Molla *et al* 2014b, Loevinsohn 2015, Perez-Saez *et al* 2017).

This finding reinforces Schutte *et al*'s (2018) conceptual framework that connects climate change and migration, depicting a bi-directional arrow between health and mobility because migration is a determinant of health and, conversely, health can shape migration decisions (Abubakar *et al* 2018, Vearey *et al* 2019). In other words, migration can be both an adaptive response (e.g. a response in part to health risks) and a 'crisis' (e.g. where migration itself contributes to health risks and other vulnerabilities) (Tacoli 2009). Accordingly, health concerns can arise both from preventing or deterring migration as well as via poorly managed migration (Etzold *et al* 2014, Dinkelman 2017, Vearey *et al* 2019). As reflected in this assessment where the health of both host and origin communities was examined in the context of climate-related migration.

The findings highlight the following health concerns for people involved in or affected by migration in a changing climate

- (a) *Altered distribution of infectious disease* (see table 4 study: study 1, 7, 27, 28, 33, 34, 38, 40, 43).

A few studies examined connections between climatic changes, migration, and HIV/AIDS. In India, drought-affected farmers migrating to urban areas were found to have increased risk of contracting HIV and other sexually transmitted infectious diseases (Anupama *et al* 2016). In Malawi, a positive and non-linear relationship was demonstrated between HIV prevalence and the extent of rural hunger, in the context of a surge of rural-urban migration during drought, particularly by young women (Loevinsohn 2015). This is consistent with contemporary accounts of increased transactional sex in times of famine, with hunger compromising immune function.

Other infectious diseases were also examined. In Bangladesh, a cross-sectional study found a high

incidence of malaria, dengue, childhood diarrhea, and pneumonia among members of climate-vulnerable communities; almost half of the respondents had been homeless for more than a month due to floods and cyclones in the preceding ten years (Kabir *et al* 2016). Another study in Bangladesh comparing people displaced primarily due to environmental change with people displaced mainly due to political reasons, found poor living and sanitation conditions contributed to significant morbidity from infectious disease, particularly diarrhea and pneumonia. The study concluded that people displaced by climate threats in Bangladesh were more vulnerable to disease than people displaced for other reasons. The difference is explained as unequal exposure to poor household environmental conditions (water and air) (Molla *et al* 2014a). In Nigeria, increased prevalence of malaria, typhoid, cholera, diarrhea, dysentery, influenza, and tuberculosis amongst fishing communities was observed in the context of migration due to sea-level rise and coastal flooding (Oyekale *et al* 2013). In Bangladesh, hazard related forced migration led to migrant ill-health, as a result of both intense physical labor and poor living conditions. Permanent migrants faced similar problems due to the longer-term hazards of living in urban slums (Penning-Rowsell *et al* 2013). Another study in Bangladesh found that slum migration in the context of climatic disasters led to an increased risk of health issues from unhygienic and overcrowded living conditions and a lack of access to WaSH. Climate migrants suffered from undernutrition, micro-nutrient deficiencies (increasing their risk of contracting infectious diseases), and notably, different waterborne diseases when compared to the host community (Rahaman *et al* 2018).

(b) *Non-communicable diseases (NCDs)*

In the context of an increasing burden of NCDs globally, it is perhaps unsurprising that they are also a concern for people on the move in the context of a changing climate. Some studies indicate that dietary transitions that migrants experience in destination sites may increase the risk of diet-related NCDs (Ahlgren *et al* 2014) supporting similar research (Galbete *et al* 2018, Danquah *et al* 2018, Boateng *et al* 2019) (see table 4: study 4, 12, 29, 33, 34). The authors of one study argue that in the Marshall Islands—as climate change undermines the capacity for traditional food cropping, imported foods contribute to health risks, and people migrate to urban centers—the prevalence of chronic diseases will increase (Ahlgren *et al* 2014). Other studies reveal difficulties migrants face in managing NCDs in the context of climate-related migration with links to barriers in accessing healthcare. This finding builds on recent research on the syndemic of climate change, obesity, and malnutrition (Swinburn *et al* 2019) and pathways

between climate change and NCDs (Savage *et al* 2019) (See table 4: study 10, 12, 13, 24, 29).

- (c) Psychosocial health issues emerge where displaced people are separated from social networks (Loevinsohn 2015, Dinkelmann 2017), face socio-economic deprivations (Hutton and Haque 2003) and experience the degradation of ecosystem services (Tschakert *et al* 2013) and other fundamental resources that are key determinants of identity such as land ownership and connection to country (See table 4: study 9, 11, 23, 30, 47, 50).

Following floods in Pakistan, a cross-sectional study detected high levels of depression, aggression, and Post Traumatic Stress Disorder (PTSD) among Internally Displaced Persons (IDPs). Risk factors for mental disorders related to conditions in shelters (Atta *et al* 2013). In Taiwan, elderly people relocated by the government post-Typhoon Morakot, experienced high levels of PTSD symptomatology (Chen *et al* 2011). Concerning river-bank erosion in Bangladesh, migrants were found to have significantly higher levels of distress than non-migrants, but rather owing to socio-economic deprivation than to displacement (Hutton and Haque 2003). In a Senegalese farming community where migration is used as an adaptive strategy, poor health was raised as a problem during periods with dust storms and prolonged rain. Further ‘reduced solidarity’ was identified as an indirect impact of adverse climatic changes (Mertz *et al* 2009). In Ghana, a study that explored migration in the context of climate change found that environmental change can trigger acute feelings of sadness, fear, anger, disappointment, and helplessness (Tschakert *et al* 2013). In Shishmaref, Alaska, residents experience ice melt, erosion, and habitual flooding without political commitment for permanent relocation. This uncertainty, in addition to the psychological impacts of floods causes significant stress (Wolsko and Marino 2016).

Mental health issues were identified as prominent in situations of forced displacement, particularly in contexts of increased violence. This is of concern given that some research suggests that deviations from normal precipitation and mean temperatures increase the risk of intergroup conflict (Hsiang *et al* 2013). Whilst the climate change—conflict relation is not observed in every context, there is substantial agreement that some conditions make this relationship more likely, such as agricultural dependence (Koubi 2019), political exclusion, a history of conflict and high levels of poverty (Uexkull *et al* 2016)

- (d) *Access to health care*; Mobile populations face barriers to accessing health care. For example, in Northern Russia due to early ice melt and more open water, herders face extra safety risks and

delays in accessing healthcare (Amstislavski *et al* 2013). Access to health care was considered a key relocation outcome for three small climate-vulnerable coastal communities in the Solomon Islands. Residents of one relocated community reported limited access to healthcare services post-relocation (Albert *et al* 2018). Access to healthcare was also disrupted by the extreme weather events themselves (Coker *et al* 2006, Behr and Diaz 2013). Studies recommend reducing financial, geographical, and cultural barriers to accessing healthcare (See table 4: study 4, 5, 10, 20, 21, 25, 27, 21). Such a reorientation of health systems has been referred to as 'migrant-sensitive health systems' that systematically incorporate the needs of migrants into health financing, policy, planning, implementation, and evaluation (Villa and Raviglione 2019). Migrant inclusive health systems might consider epidemiological profiles of the migrant population as well as cultural, language, and socioeconomic factors (IOM 2019b). Recommendations to make health systems migrant inclusive and climate-resilient (WHO 2016, Schwerdtle *et al* 2018) have synergies with general health systems strengthening and goals towards universal health coverage that aims to ensure all individuals and communities receive essential, quality health services from health promotion to prevention, treatment and rehabilitation and palliative care. Apart from being sensitive to migrant experience and healthcare needs, health systems also need to be climate resilient such that they can better anticipate prevent, prepare for and manage climate-related health risks (WHO 2016).

4.4. Food and water security mediates mobility responses and health outcomes in the context of a changing climate

Health extends beyond the remit of the health sector and many sectors, especially those related to food systems and water management, have health determining functions. This is the basis of the 'health in all policies approach'. The fourth key finding is that food and water security (including access to WaSH) represents an important mediator of both mobility responses and health outcomes in the context of a changing climate. The negative health impacts of climate-related migration for mobile populations and sending and host communities can be mitigated by ensuring access to climate-resilient WaSH infrastructure and strengthening food security (See figure 4).

Extensive and growing literature documents the links between climate change and agricultural yield with newer evidence looking at the impact of climate on the nutritional quality of staple crops (Myers *et al* 2017, FAO 2019). Agricultural yield is a direct driver of food security and is directly tied to both climate

change and migration (Afolayan and Adelekan 1999, Feng *et al* 2010, Massey *et al* 2010, Mueller *et al* 2014, Cai *et al* 2016). Whilst some of this research was captured in this assessment if there was not a sufficient health focus it was not included. That is to say if the focus was on agriculture, economy, or livelihoods as opposed to food and nutrition security or malnutrition in any form.

To illustrate how food and water security are intertwined in the matrix of migrant health in the context of climate change (See figure 4), Adams (2016) describes immobile populations in Peru that, due to temperature extremes, excessive precipitation, abrupt seasonal weather changes, and drought, are exposed to reduced crop productivity and water scarcity leading to human and animal disease. In this case, health impacts exist because populations do not move. Food insecurity is not acting as a migration driver but rather negatively affecting people in place. Another study in Tanzania (Afifi *et al* 2014), reported a positive relationship between rainfall shortage and out-migration after taking other important demographic and socio-economic factors into account. In this case, food security is the mechanism through which rainfall variability affects human mobility. Whilst people ranked migration as a key coping strategy and said they 'follow the water', migration also negatively affected families where dependents were neglected for long periods (Afifi *et al* 2014).

Similarly, Heaney and Winter (2016) found that increased drought frequency and duration in Kenya caused food and water shortages that render the Massai incapable of sustaining their livestock, leading to rural-urban migration. Whilst remittances, invested in food and healthcare, benefitted sending communities, the migrants themselves struggled with mental health issues (stress, unhappiness, loneliness) related to social isolation and experienced barriers to accessing healthcare which they used as a last resort and only for physical complaints (Heaney and Winter 2016).

Drought impacts negatively affecting food and water security in Afghanistan have led to social impacts including water-related conflicts, migration, malnutrition, poor health, and a sense of hopelessness and loss (Iqbal *et al* 2018). In this context, farmers said their religious beliefs helped them withstand long periods of drought and to refrain from committing suicide. Disproportionately affecting low-income farming households, drought also affected food choices with families reporting an inability to meet the goal of consuming nutritious foods (Iqbal *et al* 2018).

In Vanuatu, migration increased vulnerability in already vulnerable communities where seasonal migration significantly compromised local agricultural production and food security in sending communities (Craven 2015). Other research shows increased reliance on imported foods may increase

the risk of diet-related NCDs (Ahlgren *et al* 2014, Savage *et al* 2019). While remittances served to finance health, education, and maintain food security in times of crisis, there is a risk that remittances will be insufficient to cover the loss of sustenance food production. Edwards (2013) found food shortages drove relocation and Etzold *et al* (2014) discovered the most food-secure people did not need to migrate to adapt to the negative effects of rainfall vulnerability.

These studies highlight the differential health impacts on different populations engaged in or affected by climate-related migration. They illustrate how food and water insecurity can contribute to migration decisions and affect health, and also how migration in the context of climate change can reduce food and water security in sites of relocation with flow-on consequences for health. This supports other research that people may move as an adaptive response to climate vulnerabilities including food and water insecurity or conversely, that they may move into sites of higher health risk (Vinke 2019).

Policy responses differentiated by mobility characteristics with consideration to populations at origin as well as mobile and host communities may mitigate the negative health impacts or at least not contribute to them further.

4.5. The integration of climate data

The fifth finding of this systematic assessment relates to the variable degree to which climate, meteorological and environmental data were integrated into the individual studies to link the migration and health phenomenon to climate change (see table 3). Based on the included studies, the degree to which this data was integrated is categorized into three approaches;

- (a) The study referred to weather or climate change in the narrative, and/or the environmental event can be linked to climate impacts (e.g. hurricane, rainfall variability), but did not display any meteorological data (See table 4: studies 2, 4, 6, 9–13, 15–21, 23, 25, 28, 29, 31, 33, 34, 36, 38–41, 43, 45, 46, 48–50).
- (b) The study extracted meteorological data and conducted their analyses describing weather (short period, or point in time) or climate information independent of migration or health data (data over several years and aggregated) (See table 4: studies 1, 3, 5, 7, 8, 26, 30, 32, 35, 42, 44, 47).
- (c) The study extracted own meteorological data and overlaid and analyzed climate data (for example, as a comparison between drought vs. non-drought years) with migration and/or health data. (See table 4: studies 14, 22, 24, 27, 37)
- (d) Whilst the degree of climate and environmental data integration required depends on the specific research question, the variability

raises several questions, including the amount of climate data that are required to produce robust evidence linking climate impacts to human migration (and health), how these data are accounted for in evidence synthesis and the basis on which to link data demonstrating environmental changes to anthropogenic climate change (Rosenzweig and Neofotis 2013, Ebi *et al* 2017).

Whilst there are good examples of robust integration of climate data into mobility and health data (Hsiang *et al* 2013, Burke *et al* 2015) to the authors' knowledge, there is no recognized matrix or accepted framework to guide researchers and maintain quality in climate, migration and health research. There is a need to further refine and build upon the three approaches outlined above and to develop a typology to guide future climate change, health, and migration research. As recognition of the impacts of climate change on health expands, there is a risk that quality will be compromised if public health researchers superficially link their findings to climate change without carefully delineating weather from climate and natural variability from climate change and examining the causal evidence.

We find there are diverse methodological approaches to studies of the climate-migration-health nexus. In-depth, qualitative case studies featured prominently in this assessment and align well to this research field considering mobility decisions are influenced, among a range of complex and interacting factors, by experiences and perceptions. Yet, due to the methodological complexity of examining human and natural systems over different temporospatial scales, the question arises as to what design would yield the 'best available evidence' for this emerging field of nexus research? Choice of method will be determined by the research questions and context yet there will be value in; quantitative survey design, for example, comparing health outcomes of mobile with non-mobile households in sites of climate risk (See table 4: study 7, 13, 17, 18, 20, 23, 26, 47); analysis and synthesis of large-scale migration, health and environmental datasets (See table 4: study 14, 15, 21, 37, 49); and qualitative methods that seek to understand site-specific migration drivers and health experiences, including in smaller community settings (See table 4: study 13, 18, 20, 29, 30, 31, 32, 43, 47, 50).

Innovative, transdisciplinary approaches are also required such as incorporating climate data into routine epidemiological surveillance systems, early warning and risk assessment for climate-sensitive diseases, and other types of disasters, epidemics, and nutritional crises. Innovative tools and methods would seek to strengthen data management, observations, develop climate-relevant services (Thomson and Mason 2019), and fill existing migration and health data gaps that constrain

evidence-based policy and practice. Apart from innovative approaches, there is also a need to enable this type of research in the funding environment for example, rapid financing of research to track and understand mobility before, during, and after climate hazards and stressors. A large proportion of this research is retrospective which has clear limitations particularly in terms of recall bias.

Some obstacles preventing research engagement in this area may be that the standard epidemiological methods are not fit for purpose for the complexities of health and migration in the context of a changing climate. This leads to difficulties in identifying causal links between climate change, mobility responses, and human health. And yet, as identified by the Global Compact for Migration (UNHCR 2018a), there is a need to collect and use accurate data to inform evidence-based policy. Longitudinal migration and health data such as that from the Health and Demographic Surveillance System (HDSS) could be further employed by transdisciplinary teams to answer important questions about climate-migration-health connections and their policy significance. Linking back to the motivation for this synthesis research, international agreements and frameworks such as the Global Compact for Migration and the SDGs would be strengthened by strategic research to address climate-migration-health knowledge gaps and build on the findings of this systematic literature assessment.

Health outcomes in the context of human mobility and climate change are context-dependent and are shaped by diverse economic, environmental, political, social, and demographic factors. Broad systems thinking is required that moves beyond push and pull factors and the linear origin and destination understanding, and rather interrogate complex causal chains, triggers, thresholds, health consequences, and policy and practice significance (Future Earth 2019). Research that addresses internal and rural-urban migration, as well as migration into sites of climate risk (D'Amato *et al* 2011, Vinke 2019), will be useful as these are dominant patterns of migration at the current 1 degree of warming. It will be of value to go beyond considering vulnerable populations and health risks, but also collect data on resilience and adaptation that support health and wellbeing for those on the move in a warming world.

4.6. Strengths and limitations

The strengths of this research include blinded study selection and quality appraisal as well as the extensive search in four literature databases. In terms of limitations, the inclusion of English and German studies published in academic journals may have led to selection bias.

Concerning study design, conventional systematic literature reviews (SLRs) are predominantly used to analyze quantitative empirical data in

the health sciences with a focus on randomized controlled trials (Berrang-Ford *et al* 2015). There are very different perceptions of what constitutes an SLR in social, health, and environmental sciences, and definitions of minimal standards are contested. However, there is consensus that one size does not fit all (Berrang-Ford *et al* 2015).

We undertook a focused review of the literature that sought to answer a specific research question using pre-defined eligibility criteria for documents (Berrang-Ford *et al* 2015). We followed standard methodological steps: (1) define the research question and scope of the study, (2) document selection, including development of inclusion and exclusion criteria, (3) critical appraisal of study quality, (4) analyze and synthesize evidence, quantitative and/or qualitative, and (5) present results (Petticrew and Roberts 2006, Higgins and Green 2008, Barth and Thomas 2012). We called this research a systematic literature assessment due to the need to adapt conventional methods to answer the research question and to account for the broad types of studies captured. Some choices were made that arguably make this secondary research less like a standard SLR such as the exclusion of grey literature, combining heterogeneous studies in a meta-synthesis and the fact that we cannot report on publication bias, due to the inclusion of heterogeneous studies that used different outcomes and different effect measures.

The decision to exclude grey literature may have led to the omission of some important findings yet peer-reviewed studies aligned better with the research aim and specific objectives to synthesize empirical research. Primary studies within grey literature reports should have been captured by the search strategy.

Ambiguity in reporting within eligible studies may have led to over or underestimation of methodological quality. Caution is needed in interpreting these studies because secondary data were often used with other objectives and because some studies used small sample groups (especially qualitative case studies) with findings that could not be generalized to larger groups. The three modeling studies (See table 4: studies 1, 19, 40) were not assessed for quality because it was not possible to use MMAT for modeling studies.

Although the criteria for inclusion in terms of climate change are clearly presented, many eligible studies suggest potential links to climate change rather than demonstrate the link with climate data. Apart from a few particular examples (e.g. Perma-frost melt, Alaska) other environmental risks are assumed to be linked to climate change (e.g. river-bank erosion, cyclone, flood). Whilst the likelihood of their occurrence and/or severity may increase with climate change, other factors may be responsible for or contribute to the climate hazard

such as natural climate variability or development activities.

Although the inclusion of all three elements of the climate- migration-health nexus was required for inclusion in this assessment, some studies still focused on a 'dyad' within the nexus, whereby climate change was considered, yet either migration or health was underexplored. Subsequently, extractable data for these underexplored elements was at times inadequate and required interpretation. This limitation was unavoidable, in an assessment that aimed to use systems thinking in a research environment that is essentially still in operating in silos.

4.7. Implications

This assessment identified some well-represented knowledge clusters that are amenable to synthesis via systematic review including the health impacts of climate-related forced displacement in Bangladesh and the characteristics of effective planned relocation governance. Underrepresented areas of research that would benefit from further primary research include the health considerations for trapped populations (Hirvonen 2016), the mental health impacts of climate-related migration, and the gendered health impacts of climate-related migration. Further research could analyze the question of quality in terms of climate data integration in climate change-related public health research. Finally, research could examine how the syndemic of climate change, obesity, and undernutrition (Swinburn *et al* 2019) interacts with non-communicable disease management and migration.

5. Conclusion

Exploring the pathways through which climate change, migration, and health interact is a complex challenge. Considering climate change threatens decades of global health gains, health equity, and human rights, there is significant impetus to better understand how migrant health can be protected and promoted in the context of accelerating climate change. This understanding requires transdisciplinary research, consensus on how to integrate climate data, understanding of the pathways via which climate impacts shape mobility, and policy-relevant research.

This assessment revealed that within the extensive literature in both dyads (climate change and health; climate change and migration) there are proportionately few studies exploring this nexus. Since migration frameworks encourage a whole of government approach (Abubakar *et al* 2018, IOM 2020) and climate change and health frameworks rely on intersectoral collaboration (IPCC 2014, WHO 2016), the research community will need to keep pace by adopting systems thinking to explore this type of nexus research and provide policy-relevant actionable

insights. As a minimum, climate change and health can be incorporated into migration research, and migration considered a determinant of health, as well as an important consideration within climate change adaptation frameworks.

The findings maintain that relationships between climate change, migration, and health are strongly heterogeneous and that there are no uniform or global solutions. Given the diversity of mobility responses in the context of climate change, responsive approaches are required that address the vulnerabilities of communities at risk of, or involved in, forced migration, whilst supporting the adaptive potential of mobility responses.

The quality appraisal indicated that overall the quality of included studies was high. However, an incidental finding related to quality was the limited degree to which meteorological and climate data are integrated into studies claiming to explore the health and migration effects of climate change. This pertains to climate change and health research more broadly and warrants further analysis and consultation with climate scientists and meteorologists to develop normative terminology, standards, and benchmarks. IPCC definitions could support this process.

Prominent health issues that may particularly affect migrants in the context of climate change according to this assessment include; changing patterns of infectious disease; the emergence and management of non-communicable disease; psychosocial issues and; access to healthcare. Further, food and water security represent an important mediator of both mobility responses and health outcomes in the context of a changing climate. These findings lead to recommendations to develop migrant inclusive and climate-resilient health systems, which has synergies with general health systems strengthening and universal health care, and to support the sustainable development agenda that seeks to leave no one behind, especially vulnerable populations engaged in or affected by climate-related mobility.

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Data availability statement

The data that support the findings of this study are available as supplementary materials from the

corresponding author upon reasonable request and include data extraction spreadsheet, RoSES Reporting spreadsheet, Quality Appraisal tables; individual and collated by study design.

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