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# The Relationship between Health and Environment under the Lens of Climate Change Insights for Policymaker: A Scoping Review

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## Abstract

**Background:** Climate change is a significant global challenge with wide-ranging impacts on human health and the environment. There is growing recognition of the intricate connections between climatic changes and public health outcomes. Environmental degradation driven by climate change – including rising temperatures, shifting weather patterns, and extreme weather events – has direct and indirect effects on human well-being. These effects pose complex challenges that demand comprehensive understanding and effective policy responses. Aim: This review aims to investigate and comprehensively understand the relationship between health and the environment in the context of climate change. By examining the multifaceted dimensions of this relationship ranging from health impacts to policy responses. The review seeks to provide insights to inform policymakers in designing and implementing effective climate change adaptation and mitigation strategies that safeguard public health.

**Methods:** A scoping review approach was used in this study as an effective method for synthesising and evaluating existing literature following Arksey and O'Malley's framework, enhanced by contemporary guidelines from [29]. This method allows for a thorough scoping of 40 articles in the current body of literature while embracing many views, theoretical frameworks, and empirical data.

**Findings:** The multifaceted interaction between direct and indirect health effects arising from climate change and environmental degradation underscores the complexity of the health-environment relationship. As climate change exacerbates the frequency and intensity of extreme events, alters ecosystems, and disrupts food systems, the implications for human health become increasingly intricate and interwoven. Policy interventions aimed at addressing these effects must adopt a holistic approach, accounting for the interconnections between direct and indirect pathways.

Furthermore, we explored the regional disparities in vulnerability to these health effects and the strategies policymakers can adopt to mitigate their impacts.

**Conclusion:** The integration of health considerations into climate change adaptation and mitigation efforts is imperative for fostering comprehensive, effective, and sustainable policies. The Health Impact Assessment framework, co-benefits recognition, community engagement, health system resilience, and international collaboration are pivotal pathways to achieving this integration.

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## 1. Introduction

Climate change represents one of the foremost global challenges of the twenty-first century, profoundly impacting various dimensions of human existence, notably public health and environmental stability [31].

Driven largely by human activities – notably the burning of fossil fuels and deforestation – atmospheric greenhouse gas concentrations have risen sharply, leading to global warming and associated shifts in climate patterns. These shifts include increased average temperatures, more frequent and intense extreme weather events (such as heatwaves, droughts, heavy rainfall, and hurricanes), sea-level rise, and changing patterns of precipitation. Collectively, such environmental changes are disrupting natural ecosystems and the life-sustaining services they provide, in turn affecting human well-being. Recently, extensive attention has been dedicated to the complex nexus linking climate variability, ecological systems, and human health outcomes. Evidence increasingly highlights how shifts in climate patterns adversely affect both human health and ecosystem functionality, driving biodiversity loss and ecosystem degradation [35, 42]. Biodiverse ecosystems deliver critical health-supporting services such as air and water purification, crop pollination, disease regulation, and nutrient cycling. Therefore, ecological disruptions inevitably compromise human health and well-being.

Air quality, closely tied to environmental health, has emerged as a prominent concern within climate discourse, given that changing temperature and precipitation patterns influence the formation and dispersion of pollutants such as ground-level ozone and particulate matter. These pollutants exacerbate respiratory and cardiovascular diseases, particularly within densely populated urban centres marked by heightened vehicular and industrial emissions [12, 39]. There is evidence that climate change is acting as a "threat multiplier" intersecting with factors like poverty, conflict, and urbanization to heighten health risks. For example, climate-induced crop failures can contribute to higher food prices and economic instability, indirectly affecting nutrition and health, especially in low-income populations [46].

The interdependence of climate change and health manifests through numerous direct and indirect pathways, including heightened extreme weather events, altered patterns of vector-borne diseases, increased heat stress, deteriorating air quality, and disruptions in food and water security [52, 6, 8]. Notably, the distribution of these impacts is highly uneven, disproportionately affecting vulnerable populations such as low-income communities, marginalized ethnic groups, and populations in developing nations, largely due to limited adaptive capacities, inadequate healthcare infrastructure, and socioeconomic disparities [44, 52]. Understanding these differential vulnerabilities is vital for designing targeted and equitable health interventions and policies.

In response to climate-related health risks, various national and international policy frameworks have been established. Agreements such as the Paris Accord demonstrate global commitments toward greenhouse gas reduction and climate mitigation efforts [44]. Concurrently, adaptation strategies aim to enhance community resilience and public health protection [26]. However, critical evaluation of these policies' effectiveness remains essential to ensure they effectively minimize health vulnerabilities and bolster adaptive capacities across diverse contexts.

Despite significant advances in understanding climate-health interactions, effective implementation of adaptation measures in the health sector encounters numerous barriers. Among these challenges are limited financial resources, insufficient intersectoral coordination, and inadequate capacity-building efforts, all of which undermine health systems' preparedness and responsiveness to climate risks [17]. Addressing these obstacles is crucial to ensuring comprehensive and resilient public health frameworks.

Integrating health perspectives into climate policy is increasingly recognized as fundamental to developing holistic, sustainable responses [9]. Researchers and policymakers advocate for embedding health co-benefits into mitigation strategies, ensuring health-centric adaptation planning, and fostering interdisciplinary collaboration between health and environmental sectors to improve policy coherence and effectiveness [9, 13]. Policymakers thus face the imperative of formulating comprehensive, evidence-based strategies addressing both immediate health concerns and long-term sustainability goals [41, 24].

Significant research gaps persist despite extensive studies exploring health-environment-climate linkages. More region-specific investigations are needed to better understand differentiated climate impacts across communities, alongside detailed examinations of synergies and conflicts between climate mitigation and adaptation strategies in relation to health outcomes [11, 39]. Addressing these gaps through targeted research is essential for informed policy-making.

This scoping review aims to comprehensively examine the health-environment relationship within climate change contexts, identifying key health impacts, assessing regional and demographic disparities, evaluating existing policy effectiveness, and highlighting implementation challenges. The ultimate goal is to provide actionable insights for policymakers tasked with developing robust adaptation and mitigation strategies to safeguard human health against climate change impacts.

### Study Objectives and Research Questions

This scoping review pursues four primary objectives: (1) to categorize key health impacts associated with climate change and environmental degradation, mapping both direct and indirect outcomes; (2) to analyze variations in health impacts across regions and populations; (3) to identify and evaluate the effectiveness of existing policy frameworks addressing climate-health risks; and (4) to explore barriers hindering effective implementation of climate adaptation strategies within the health sector.

Accordingly, two research questions (RQs) guide the review: RQ1 explores the range and distribution of climate-related health impacts, while RQ2 investigates existing mitigation policies, their effectiveness, and the challenges faced in implementation. Together, these questions aim to comprehensively assess how climate change affects health, where vulnerabilities lie, and how policy responses can be strengthened.

## Methods

### Study Design

A scoping review was conducted, incorporating qualitative, quantitative, mixed-method research, and grey literature. The review adhered to guidelines proposed by [3], including identifying relevant research questions, locating and selecting pertinent articles, charting data, and summarising findings. Additionally, contemporary guidelines emphasizing flexibility in the inclusion of diverse literature types were employed, highlighting the utility of scoping reviews for identifying research gaps and summarising evidence to inform future systematic reviews or policy recommendations [29].

**Identifying The Research Question**

What are the health impacts associated with environmental degradation and how vary are the health impacts amongst different populations/ regions?

How effective are the existing policies and strategies aimed at mitigating the health risk of climate change and the potential barriers to implementing climate change adaptation strategies within the health sectors amongst different regions/populations?

**Search Strategy**

An extensive literature search was conducted across PubMed, Web of Science, Scopus, and CINAHL Plus, utilizing targeted keywords such "climate change, " "weather, " "seasonality, " "well-being, " "health, " "Public health, " "environment, " "geographic, " "impacts, " "effect, " "degradation, " and "policy, " (e.g. MeSH terms in PubMed), combined with Boolean operators ("AND, " "OR") to ensure comprehensiveness. For example, a representative search query was:

("climate change" OR "global warming" OR "climatic" OR "extreme weather" OR "environmental change" OR "environmental degradation")

AND

(health OR "public health" OR well-being OR disease OR morbidity OR mortality)

AND

(policy OR policies OR adaptation OR mitigation OR "health sector" OR "health system" OR strategy OR governance).

The PICO framework (see Table 1) guided the exploration of climate-health relationships, policy effectiveness, and adaptation barriers across diverse regions and populations. Supplementary sources from Google Scholar, Google to locate policy reports from organizations like the World Health Organization, United Nations Framework Convention on Climate Change (UNFCCC), United Nations Environment Programme (UNEP), and governmental health or environment departments (for example, the UK's Department of Health and Social Care or Public Health England), and bibliographic reviews were included to capture additional academic articles, other governmental documents, and grey literature pertinent to the research objectives.

In total, 1, 235 records were identified and screened. After applying the eligibility criteria as highlighted in Table 2, 40 articles were included in the final review. A PRISMA-style flow diagram was used to illustrate the study selection process (see Figure 1)

**Data Extraction and Quality Assessment**

Data from each of the 40 included sources were charted using a structured extraction form (implemented in Microsoft Excel). Impacts were categorized into direct and indirect consequences. Policies were defined as measures to slow climate change and prepare health sectors for climate-related challenges. Strategies addressed immediate and long-term adaptation needs in healthcare systems to sustain public well-being under climate pressures [21]. We recorded bibliographic details (Author, year, publication type), the study design or approach, geographical focus, key findings relevant to climate-health impacts, and any policy or adaptation measures discussed. To organize the diverse data, we established thematic categories based on initial scoping of a subset of articles. These themes included: (1) Environmental/climate factors addressed (e.g. heat, extreme weather, vector habitat, air quality, etc.); (2) Health outcomes addressed (e.g. heat-related illness, infectious disease, mental health, nutrition); (3) Whether direct and/or indirect pathways were considered; (4) Mitigation or adaptation policies discussed, if any; (5) Evidence of regional or population disparities in impacts; and (6) Key conclusions or recommendations of the study. We also noted whether each study explicitly mentioned co-benefits (positive side-effects of climate actions on health) or trade-offs, as this was of special interest. By charting data in this way, we could compare across studies and identify common patterns (see Table 3). For instance, we tallied how many studies dealt with certain health outcomes or certain regions to get a sense of research distribution (e.g. a majority might have addressed heat stress and infectious disease, with fewer on mental health – which turned out to be the case). We also categorized the types of policies examined: some papers discussed national policy frameworks, others evaluated local interventions (like early warning systems or heat action plans), and others provided high-level recommendations. This helped us structure the results section by thematic areas rather than summarizing study-by-study, which is more useful for a narrative synthesis in a scoping review. We did not formally quantitatively synthesize outcomes (no meta-analysis was performed, given the heterogeneity of study designs and metrics). Instead, we summarised the findings descriptively and analytically. During the collating and summarizing stage, we employed a thematic analysis approach: reading through the extracted data repeatedly, clustering similar findings together, and iteratively refining theme definitions. Four overarching thematic domains emerged that aligned with our research questions: Health Impact Categories, Regional/Population Vulnerabilities, Policy Frameworks and Strategies, and Barriers/Challenges to Implementation. Within each domain, sub-themes were identified (for example, within health impacts: direct vs indirect effects; within policies: integration and co-benefits, equity considerations, etc.). These domains form the basis of how the Results and Discussion are structured. Throughout the synthesis, we have ensured to retain the original in-text citations from the sources to credit findings appropriately and allow readers to trace evidenceWhere this report integrates multiple sources to make a single point (such as a general statement supported by several studies), multiple citations are provided. It should be noted that, due to the scoping nature, the review encompasses a broad but shallow aggregation of evidence: we prioritize coverage of the range of issues over detailed critique of each study. This approach suits the aim of mapping the field.

**Findings**

Following the established methodology, a total of 40 publications—comprising 30 peer-reviewed journal articles and 10 policy or governmental reports—were included in this scoping review. Publications dated from 2008 to 2022, covering foundational research and recent developments. Geographically, about one-third of the sources were global or multi-region studies (e.g., the Lancet Countdown reports), one-third focused on specific countries or regions (e.g., sub-Saharan Africa, Europe, South Asia, small island states), and the remaining addressed city- or community-level analyses.

To present the findings systematically, four main thematic areas were identified:

1. Health Impacts of Climate Change (Direct and Indirect

Pathways)
2. Regional and Population Disparities in Health Impacts
3. Policy Frameworks and Strategies for Mitigating Health Risks.
4. Barriers and Challenges in Implementing Health Adaptation Strategies.

Although some natural overlap exists among these themes, evidence was organized to minimize repetition and maintain coherence.

**1. Health Impacts of Climate Change: Direct vs Indirect Pathways**

- **Direct Health Impacts:** Over 80% of included studies focused on the direct health effects of climate change, predominantly highlighting extreme weather events and temperature fluctuations. Heatwaves emerged as a consistent concern, with increased incidences of heat stress, heatstroke, and mortality [47] noted that the introduction of heat-health action plans in European cities correlated with reduced heatwave mortality. Vulnerable groups—elderly individuals, young children, and those with cardiovascular or respiratory conditions—were consistently identified across diverse climates, including the UK, where the 2019 heatwave caused notable increases in emergency callouts and deaths [8].

  In addition to heat, extreme weather events such as floods and wildfires presented direct health risks [16] documented flood-related injuries and disease outbreaks due to water contamination, while [33] linked wildfire smoke exposure to respiratory disease surges. Climate-induced air quality degradation was another direct pathway, with higher temperatures exacerbating ozone and particulate pollution, as reported by [27, 28].
- **Indirect Health Impacts:** Nearly all studies acknowledged complex indirect health impacts via ecosystem changes [20, 10] provided evidence of altered vector-borne disease patterns, while [4] reported expanded malaria transmission zones in Nigeria. Dengue and Zika viruses have similarly spread into new areas [11, 31].

  Flooding and thawing permafrost have affected sanitation infrastructure, leading to water-borne diseases [14]. Food security challenges resulting from climate-induced agricultural disruption were noted by [5, 46], linking erratic rainfall to poor nutrition and health outcomes.

  Mental health consequences also surfaced, albeit less extensively quantified. Disasters were linked to trauma and PTSD [12, 24], while gradual environmental changes triggered "eco-anxiety" and solastalgia, particularly among indigenous communities [21, 14, 36].

  Overall, the findings confirm that health risks emerge from both immediate and delayed pathways, reinforceng the necessity of systems thinking in policy responses.

**2. Regional and Population Disparities in Health Impacts**

**Regional Disparities:** Substantial evidence highlighted unequal regional burdens of climate-related health impacts. Sub-Saharan Africa, characterized by limited adaptive capacity, faces expanding malaria zones [10, 17] and recurrent drought-induced malnutrition [46, 51].

South Asia's heatwave-related mortality [1] and flooding-related disease outbreaks underscore its vulnerability. Small Island Developing States (SIDS) contend with dengue outbreaks and freshwater scarcity [21].

Even in high-income regions like Europe and North America, vulnerabilities persist. Southern Europe's aging populations face elevated heat risks [48], and wildfires impact air quality in the United States and Australia. Within these countries, marginalized groups often bear disproportionate risks.

- **Population Disparities:** Socioeconomic status, age, gender, and ethnicity significantly influence vulnerability. Marginalized low-income communities are most exposed to hazards due to substandard housing and limited adaptive resources [13, 17]. Children and elderly individuals are particularly susceptible to malnutrition and heat stress [19, 42]. Gendered vulnerabilities were noted by [42], highlighting women's frontline exposure to environmental stressors. Indigenous populations, deeply tied to local ecosystems, face compounded risks [15, 13]. Recognition of these disparities reinforces the call for equity-centered climate-health policies, including in the UK, where vulnerable groups must be prioritized domestically and through international climate aid efforts.

**3. Policy Frameworks and Strategies for Mitigating Health Risks**

The review identified an expanding range of policy responses at multiple governance levels.

- **International and National Frameworks:** The Paris Agreement (2015) and initiatives like Health in All Policies integrate public health considerations into climate action. The Lancet Countdown reports [51, 52] advocate leveraging climate mitigation for health co-benefits, such as through renewable energy transitions.
- Countries have adopted Climate-Health Action Plans, e.g., France and Spain's heatwave preparedness programs, which have demonstrably reduced mortality [47]. The One Health approach, linking human, animal, and environmental health, has also gained traction in countries like Kenya and Thailand [41].
- **Health System Adaptations**: Health system resilience strategies include infrastructural fortification, supply chain reinforcement, and healthcare workforce training [26]. Vector-borne disease control innovations, such as Ethiopia's malaria early warning systems, further exemplify successful adaptation efforts. The UK's National Adaptation Programme integrates health into broader climate resilience goals, with plans to enhance NHS climate readiness and public health surveillance.
- **Health Co-benefits of Mitigation Policies**: Clean air initiatives [15, 28], promotion of active transport [36], urban greening [42], and sustainable food system reforms [45, 53] collectively demonstrate that climate policies can simultaneously improve public health outcomes.

  Despite successes, integration gaps and uneven progress across nations remain [17, 55], necessitating stronger transdisciplinary collaborations.

**4. Barriers and Challenges in Implementing Climate-Health Strategies**

Several significant challenges were identified as follows.

- **Governance Fragmentation:** Fragmented governance and poor intersectoral coordination complicate cohesive

climate-health strategies, both nationally and internationally [17].

- **Resource Constraints:** Limited financial and human resources, particularly in low- and middle-income countries, hinder adaptation efforts [54, 40].
- **Knowledge and Awareness Gaps:** Awareness deficits among healthcare professionals and the general public impede proactive adaptation measures [39, 35].
- **Institutional Inertia:** Resistance to change within institutions delays the integration of climate projections into health planning [16]
- **Equity and Justice Concerns**: Without equity considerations, adaptation initiatives risk exacerbating health inequalities [21, 38, 54].

In the UK context, maintaining momentum amid competing priorities (e.g., post-pandemic recovery) and ensuring local council resource allocation remain pressing challenges. Strengthening cross-sectoral governance structures, securing dedicated climate-health funding, investing in capacity-building, and centering marginalized communities in decision-making are critical steps toward overcoming these barriers

## Discussion

- **Climate Change and Public Health: A Complex Interplay**

Climate change, largely driven by human activities like burning fossil fuels and deforestation [20], has intensified greenhouse gas concentrations, leading to global warming and climate disruptions [32]. Severe weather events such as heatwaves, hurricanes, droughts, and heavy rainfall directly impact human health [30], particularly affecting vulnerable groups like the elderly and individuals with chronic illnesses [37].

Climate change also fosters conditions conducive to the spread of infectious diseases via vectors like mosquitoes and ticks, altering disease patterns globally [20]. The Eco-Health Theory [11] and the Conceptual Model of Climate Change and Health [39] explain how environmental disruptions cascade into human health challenges, reinforcing the urgent need for integrated climate-health responses.

- **Direct and Indirect Health Effects of Climate Change**

Direct effects stem from immediate environmental changes. Extreme weather events lead to heat-related illnesses, respiratory diseases due to poor air quality [24, 41], and injuries or deaths [36]. Epidemiological data link climate conditions with the prevalence of diseases like hand, foot, and mouth disease [33].

Indirect effects are more complex, involving disrupted food systems and rising malnutrition risks [36, 12]. Changes in ecosystems modify vector-borne disease transmission [54, 31]. Mental health impacts are significant, with climate-induced stress and displacement leading to heightened anxiety, depression, and PTSD [12, 24].

- **Health Impacts of Climate Change**

Higher temperatures escalate heat-related mortality [17] and vector-borne diseases [1]. Waterborne illnesses are exacerbated by compromised water systems post-flooding [14, 16]. Agricultural disruptions reduce crop yields, worsening food insecurity [19].

Mental health burdens intensify under frequent disasters and displacement [38, 12], while socioeconomic inequalities are magnified by disproportionate climate impacts on marginalized populations [46, 31].

- **Regional Disparities and Vulnerable Populations**

Environmental justice frameworks show marginalized communities bear the brunt of climate-health hazards [21, 30]. Socioeconomic status, demographic characteristics, and geographic location influence vulnerability [32, 43].

Sub-Saharan Africa faces severe food and water insecurity due to droughts and rainfall variability [51, 22]. Indigenous communities, despite possessing adaptive ecological knowledge, remain highly vulnerable due to historical disempowerment [24, 30].

- **Regional and Population Disparities**

Regions differ: low-income nations in sub-Saharan Africa and South Asia are more vulnerable due to fragile health systems [18, 14]. Climatic changes influence vector-borne diseases and water quality [17, 10, 31]. Even high-income countries face challenges, such as elderly vulnerability to heatwaves [38, 6].

Within populations, low-income, minority, and marginalized groups disproportionately suffer from poor air quality, limited resources, and elevated health risks [29, 35]. Climate-health disparities are exacerbated by seasonal changes affecting diseases like meningitis and malaria [4, 55].

*Gender dynamics* expose women to increased risks due to their societal roles and increased exposure to climate-related stressors [42, 8].

*Children* are particularly vulnerable to malnutrition, diarrheal diseases, and respiratory illnesses [16, 39]. The *elderly* face heightened susceptibility to heat and pollution [14, 31].

- **Policy Responses and Effectiveness Assessment**

Effective policy responses are crucial to mitigating climate-health risks. Frameworks like the SDGs recognize the need for integrated approaches connecting environment, health, and socioeconomics [7, 35].

- **Integrated Approach to Policy Development**

Policies must break sectoral silos, promoting intersectoral collaboration [7, 35]. The SDGs illustrate how integrated action on climate and health can drive broader societal benefits.

- **Policy Coherence and Multi-level Governance**

The Multi-Level Governance Theory advocates coordinated actions across local, national, and global scales [28, 51]. Urban infrastructure upgrades, such as climate-resilient city planning, can mitigate urban health risks.

- **Policy Effectiveness Assessment**

Assessing policy outcomes is critical. Quantitative metrics (e.g., reduced pollutant levels) and qualitative analyses (e.g., stakeholder experiences) provide insights into policy success [25, 17].

- **Adaptive Governance and Iterative Improvement**

Adaptive governance promotes flexible, learning-based policy-making responsive to new evidence and emergent risks [19, 9]. Emissions trading systems and performance reviews exemplify adaptive policy frameworks.

## Existing Policy Frameworks and Strategies

### Policy Integration and Coherence

The Paris Agreement and the One Health framework

advocate for integrated action on climate and health [12, 41]. Sweden's 2018 National Climate Change Adaptation Strategy directly addresses health vulnerabilities, informed by projections on heat-related mortality [2, 41].

**Health Co-benefits and Mitigation Strategies**

Mitigation strategies often yield health co-benefits [24]. Promoting active transport, such as cycling, reduces emissions and improves physical health [34, 36]. Copenhagen's cycling infrastructure exemplifies this.

Carbon regulation can also improve public health, but poor implementation may lead to unintended consequences [53]. Ambitious, well-funded climate policies are essential to curtail future warming.

**Vulnerable Populations and Equity Considerations**

Climate strategies must address health inequities [37]. The SDGs' commitment to "leave no one behind" guides equitable policymaking [30]. Projects like Canada's Indigenous Health Adaptation to Climate Change initiative engage marginalized communities in policy co-creation [36].

**Synergistic Approaches: Disaster Risk Reduction and Health**

Integrating disaster risk reduction with health systems boosts resilience [20]. The Sendai Framework underscores the necessity of resilient health systems in disaster scenarios [49]. Kerala's revised disaster plan after the 2018 floods exemplifies climate-sensitive health planning [7].

See Table 4 for the discussion summary of the study findings.

**Effectiveness of Policies and Strategies in Protecting Public Health and Promoting Resilience**

The increasing threats posed by climate change on public health underscore the necessity of evaluating policy interventions. Drawing from theoretical frameworks and empirical studies, this section critically analyses the outcomes of these interventions, offering nuanced insights for policymakers tasked with navigating climate-induced health risks.

**Adaptive Capacity and Societal Resilience**

The theoretical constructs of adaptive capacity and resilience frame the evaluation of policy effectiveness. Adaptive capacity reflects a system's ability to adjust and respond to evolving conditions, whereas resilience denotes the capacity to absorb shocks and maintain functionality [35, 28]. These concepts elucidate the potential of strategies to both protect health and foster societal robustness amidst climate disruptions.

**Mitigating Heat-Related Health Risks**

Heatwaves, exacerbated by climate change, have necessitated strategic policy interventions. The European Heat Health Action Plan (HHAP) exemplifies a collaborative framework incorporating early warning systems and public health strategies. Empirical evaluations by [47] revealed that cities implementing HHAP experienced a measurable decline in heat-related mortalities, affirming the efficacy of coordinated policy action.

**Air Quality Improvements and Respiratory Health Benefits**

Policies targeting air quality improvements concurrently advance climate mitigation and public health protection. Transitioning to renewable energy sources and enhancing energy efficiency are pivotal strategies. The Clean Air Act Amendments in the United States demonstrate this dual benefit. Modelling studies by [15] identified substantial reductions in premature mortality linked to enhanced air quality, thereby validating the health co-benefits of environmental legislation. Similarly, [27] emphasised the utility of monitoring air quality days as a metric for population health improvements.

**Climate Adaptation and Vector-Borne Disease Control**

Climate adaptation strategies are critical in controlling the spread of vector-borne diseases. Ethiopia's Malaria Early Warning System, integrating meteorological data with disease surveillance, stands out as an effective intervention. Research by [17] indicated significant reductions in malaria incidence where this system was operational, demonstrating the promise of adaptive, evidence-informed policies.

**Equity Outcomes and Vulnerable Populations**

Effective climate-health policies must explicitly prioritise vulnerable populations. The Social Determinants of Health framework [19] underlines the necessity of addressing the socio-economic and environmental factors shaping health disparities. The Building Resilience against Climate Effects (BRACE) framework in the United States, assessed by [9], achieved measurable reductions in health inequalities through targeted, equity-focused interventions.

**Knowledge Translation and Capacity Enhancement**

Successful policy implementation is contingent upon effective knowledge translation and robust capacity-building. The Climate Change and Health Adaptation Program in Australia demonstrated how engaging healthcare professionals enhances the translation of climate science into practice [45, 50]. This approach underscores the imperative of equipping stakeholders with the necessary expertise and tools to drive effective adaptation measures.

**Challenges to Implementing Climate Change Adaptation Strategies**

Despite progress, multiple barriers undermine effective climate-health integration. The complex interconnections among sectors such as health, environment, and disaster management complicate governance [36]. The Adaptive Governance theory posits that flexible, inclusive, and coordinated governance mechanisms are essential [34]. However, as the European Adaptation Strategy illustrates, operationalising multi-level governance remains challenging due to varying institutional capacities across member states [24].

Resource constraints further impede adaptation efforts, especially in low- and middle-income countries where health systems already face significant pressures [12]. Studies from Africa and Tanzania highlight critical gaps in infrastructure and financial resources, necessitating targeted investments [49, 14].

Awareness deficits among healthcare professionals constitute another major barrier. Research reveals limited understanding of climate-health linkages among frontline health workers, restricting the integration of climate considerations into practice [39, 8]. Moreover, institutional inertia and fragmented governance structures inhibit cohesive

climate adaptation efforts, as seen in the decentralised health systems of the United States [21, 42].

Addressing equity concerns is also critical. Indigenous populations, such as those in Northern Canada, experience compounded vulnerabilities due to geographic isolation and systemic inequities [6, 38, 54] further caution against excessive reliance on private sector engagement without equitable safeguards.

**Integrating Health Considerations through Health Impact Assessment (HIA)**

Embedding health considerations into climate policies can be achieved through systematic frameworks like Health Impact Assessment (HIA). HIA enables the evaluation of potential health impacts of proposed policies, ensuring that health outcomes are central to decision-making [28, 51]. The integration of HIAs into Australia's New South Wales Climate Change Policy Framework (2016) revealed both health and energy co-benefits from urban heat adaptation strategies [26].

**Harnessing Health Co-benefits**

Recognising the co-benefits of climate action enhances policy incentives. Transitioning to renewable energy mitigates respiratory illnesses linked to air pollution, illustrating the intertwined nature of climate and health gains [7]. China's Air Pollution Prevention and Control Action Plan (2013) successfully reduced premature mortality, demonstrating how climate policies can yield synergistic health benefits [28].

Community Engagement and Participatory Approaches

Effective adaptation demands participatory approaches that centre community voices. Bangladesh's cyclone shelters, designed through community consultation, exemplify how integrating local needs fosters both health and climate resilience [17].

**Building Health System Resilience**

Strengthening health system resilience is imperative to withstand climate-induced shocks. Lessons from Hurricane Katrina highlight the catastrophic consequences of unprepared healthcare systems and the necessity for resilient, adaptable infrastructure [19, 50, 45].

**International Collaboration and Knowledge Exchange**

Given the transboundary nature of climate risks, international collaboration is vital. Initiatives like the Global Health Security Agenda (GHSA) promote shared capacities to detect and respond to climate-sensitive disease outbreaks, reinforcing the intersection between health security and climate resilience [32, 52, 46].

**Recommendation**

To enhance the health sector's resilience to climate change, several strategic actions are proposed:

First, health must be systematically integrated into all climate policies. Health Impact Assessments (HIA) should be employed during the development of climate adaptation and mitigation strategies across sectors such as energy, transport, and housing, ensuring health benefits are maximized and harms minimized. National frameworks must prioritize public health objectives through inter-ministerial collaboration from the policy inception stage.

Second, investment in climate-resilient health systems is imperative. Governments should allocate resources for infrastructural upgrades—such as flood-resistant hospitals and cooling mechanisms during heatwaves—expand disease surveillance systems, and strengthen healthcare workforce capacity for climate-induced conditions. Global solidarity demands that high-income nations support low-income countries via funding and technology transfer initiatives.

Third, leveraging the health co-benefits of climate mitigation is crucial. Policies advancing clean energy, active transport, and sustainable food systems can simultaneously curb emissions and reduce disease burdens [15, 36, 45]. Policymakers should explicitly quantify and communicate these co-benefits to galvanize public and cross-sectoral support for ambitious climate action.

Fourth, equity must be a foundational principle. Adaptation strategies should prioritize vulnerable populations—such as low-income communities, indigenous groups, the elderly, and children—ensuring culturally appropriate, accessible interventions [8]. High-income countries should bolster global equity through targeted climate-health investments in developing regions.

Finally, governance, funding, and public awareness must be strengthened. Establishing interagency climate-health task forces, securing sustainable financing, embedding climate change education in health curricula [39], and fostering international knowledge exchange will be critical for translating plans into action at the necessary scale.

Collectively, these recommendations offer a coherent roadmap for safeguarding public health while advancing climate resilience.

**Scope Strengths, and Limitations**

This research critically explores the complex intersection of human health, environmental integrity, and climate change impacts. Drawing upon a multidisciplinary body of literature spanning epidemiology, public health, climatology, and environmental science, it consolidates and synthesizes existing knowledge to inform policy discussions. However, this reliance on current literature inherently limits the scope, with potential omission of emergent findings or non-traditional sources despite systematic scoping review efforts. While the methodology employed mitigates bias through rigorous database searches and stringent screening criteria, inadvertent exclusion of grey literature or regional studies may affect comprehensiveness. Moreover, the dynamic nature of climate policies poses temporal limitations. As scientific understanding, technological innovations, and socio-political contexts evolve, the effectiveness of specific interventions may shift. This study emphasises recent research, predominantly within the last decade, and incorporates historical analyses of major policy trajectories to contextualise findings.

Nonetheless, real-time fluctuations in policy impacts remain challenging to capture fully. To address this, the research advocates for the establishment of continuous policy

evaluation frameworks, incorporating periodic reassessments and iterative adaptation based on new evidence. Ultimately, while acknowledging its inherent constraints, this review provides a robust foundation for understanding the health-climate nexus and advancing adaptive, evidence-based policy solutions.

## Conclusion

The synthesis of empirical evidence and theoretical perspectives highlights the significant barriers impeding the integration of climate adaptation into health sector strategies. Complex governance structures, resource limitations, insufficient awareness among stakeholders, institutional inertia, and entrenched equity concerns collectively hinder effective adaptation [35, 28]. Policymakers must recognize these multifactorial challenges when designing interventions aimed at strengthening healthcare system resilience amidst escalating climate change impacts. Addressing these obstacles demands innovative governance approaches, robust resource mobilization, strategic capacity-building initiatives, and a steadfast commitment to equity and inclusion.

The integration of health considerations into climate change adaptation and mitigation efforts remains paramount for achieving resilience, sustainability, and health equity. Frameworks such as Health Impact Assessment (HIA) serve as critical tools, systematically embedding health in cross-sectoral decision-making and identifying co-benefits, trade-offs, and unintended outcomes [28, 52]. Empirical examples, such as Australia's incorporation of HIAs into the New South Wales Climate Change Policy Framework [24], demonstrate the tangible health and energy savings achievable through such integrative approaches.

Furthermore, recognising the extensive health co-benefits arising from climate mitigation policies—such as reduced air pollution and lower rates of respiratory illness—strengthens the policy rationale for integrated action [7, 35]. China's Air Pollution Prevention and Control Action Plan [28] further exemplifies how targeted environmental policies can yield profound public health improvements, reinforcing the dual imperative of climate and health goals.

Equally important is the active engagement of communities through participatory approaches. Grounded in local knowledge and contextual realities, community-centred strategies—as seen in Bangladesh's cyclone shelter initiatives—enhance the effectiveness and acceptance of health-climate interventions [17]. In parallel, bolstering health system resilience is critical; lessons from disasters like Hurricane Katrina reveal the catastrophic health consequences of system vulnerabilities [19, 50, 45].

Given the transboundary nature of climate threats, international collaboration and knowledge sharing are indispensable. Initiatives like the Global Health Security Agenda [32, 46, 51] illustrate the synergistic benefits of collective action in enhancing preparedness for climate-sensitive health risks.

In sum, the integration of health considerations into climate policy offers a pivotal opportunity to foster more resilient, equitable, and sustainable futures. Policymakers must prioritise comprehensive, health-centered frameworks, leveraging empirical insights and adaptive governance to safeguard the well-being of both current and future generations.

## Supplementary Data

### Supplement 1

**Table 1:** PICO Framework

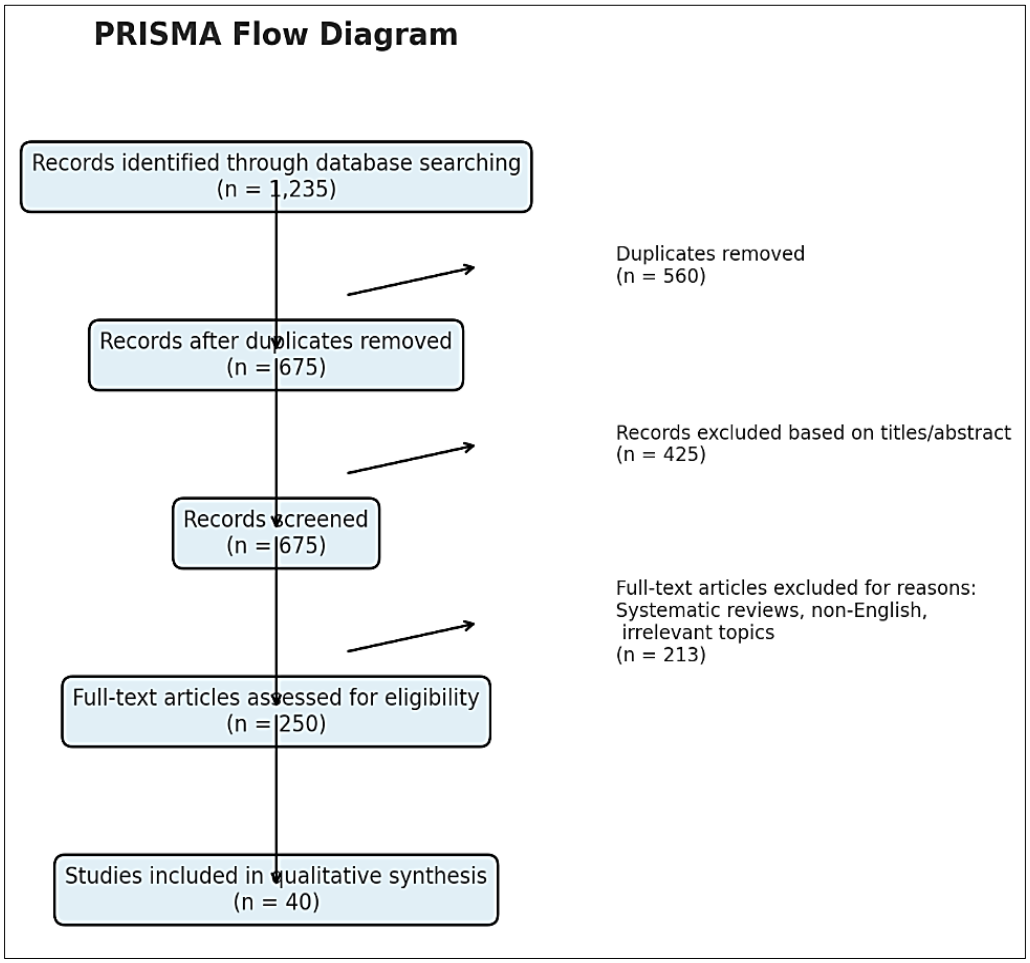
| PICO Element | Description |
|---|---|
| Population (P) | Different regions and populations affected by climate change, focusing on health impacts. |
| Intervention (I) | Existing policies and strategies aimed at mitigating the health impacts of climate change. |
| Comparison (C) | Variations across regions and populations; assessment of areas with and without effective policies/strategies. |
| Outcome (O) | Health outcomes influenced by climate change; effectiveness of adaptation policies; barriers to implementation. |

### Supplement 2

**Table 2:** Eligibility Criteria

| Criteria Type | Inclusion Criteria | Exclusion Criteria |
|---|---|---|
| **Language** | **English-language publications** | **Non-English publications** |
| Study Type | Qualitative, quantitative, mixed-method research articles, and grey literature | Scoping reviews, papers not addressing climate-health links, insufficient context or content |
| Focus | Studies addressing the impact of climate change/environmental degradation on health, and related policy initiatives | Studies focusing solely on food scarcity, hospital stays, or unrelated health outcomes |
| Publication Source | Peer-reviewed journals, government reports, scientific studies | Duplicate articles; irrelevant articles not meeting scoping review objectives |
| Relevance | Articles with sufficient data addressing study objectives, research questions, or aims | Articles failing to address the study's objectives, aim, or research questions |

### Supplement 3




**Source:** (Carney, 2015) [7]

**Fig 1:** PRISMA flow chart

**Supplement 4**

**Table 3:** Summary findings of selected studies

| Authors | Types of articles | Articles settings | Background | Objectives/ Aims | Is climate change addressed | Are health implications addressed | Co Benefit/ direct and indirect effects of climate change | Are Mitigation/ adaptation policies | Population /regional disparity | Key findings |
|---|---|---|---|---|---|---|---|---|---|---|
| Anderson and Keskitalo, 2018 [2] | AJ Qual | Sweden | X | X | X | X | - | X | X | Forestry practices in Sweden are resistant to change due to a business-as-usual mentality, climate change impacts forestry, affecting tree growth and ecosystem services, and adaptation strategies often focus on short-term profitability rather than long-term sustainability. |
| Amadi *et al*., (2018) [1] | AJ-Qual | Kenya | X | X | X | X | X | - | X | According to that research, remotely felt For predicting malaria risk, rainfall, minimal climate, and the normalised differential index of vegetation are useful indicators. The likelihood of malaria will undoubtedly increase due to future climate changes. Consequently, these variables need to be taken into account while making plans for risk assessment and malaria eradication. |
| Ayanlade *et al*., (2020) [4] | AJ-Qual | Nigeria | X | X | X | X | - | - | X | The primary discoveries of the research indicate that the transmission of malarial meningitis is significantly influenced by climate variables merely since rain offers |

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|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | an area of reproduction for mosquitoes, the malaria vector, to lay fertilised eggs and ensures optimal moist conditions to extend mosquito existence, rainfall is thought to be one of the significant factors impacting swings in the spread of malaria due to its fluctuation in the quantity and magnitude across ecosystems. |
| Bryson *et al*., (2021) [5] | AJ-Qual | Ugandan | X | X | X | X | - | - | X | The findings reported thus demonstrate that dependable accessibility and accessibility to nutrient-dense food are among the most significant factors influencing well-being among pregnant and postpartum women in rural Uganda. However, in light of climate change, proper food security is not being achieved, and it is believed that this is harming the overall well-being of mothers as well as babies. |
| Carter *et al*. 2015 [8] | AJ Qual | Uk | X | X | X | X | - | X | X | Cities play a critical role in addressing climate change through adaptation and mitigation, urban areas are vulnerable to climate impacts, necessitating capacity building, and urban adaptation requires collaboration between stakeholders and institutions. |
| Clayton and Karazsia, 2020 [11] | AJ Quan | United States | X | X/- | X | X | X/- | - | X | Climate change anxiety is a psychological response to global warming concerns, and a reliable measure of climate change anxiety has been developed, understanding climate anxiety can aid mental health interventions. |
| Curry, 2018 [15] | AJ- PC | United state | X | X | X | X | - | X | X | Establishing climate change standing is important for legal action. Courts have recognized the importance of addressing climate change impacts. Expanding legal standing can enhance climate change mitigation efforts. |
| Carney (2015) [7] | AJ-P | Uk | X | X | X | X | - | X | X | Climate change poses financial risks to stability due to its uncertain and long-term nature. Financial systems need to address these risks to ensure economic stability. Tragedy of the horizon refers to neglecting long-term risks due to short-term incentives. |
| Carter (2018) [9] | AJ- PC | Internatio nal | X | X | X | X/- | - | X | X | Anthropology provides insights into human responses to climate change. Anthropological research highlights diverse perspectives, local knowledge, and adaptation strategies. Anthropologists contribute to policy-making by understanding the cultural dimensions of climate change. |
| Chirombo *et al*., (2020) [10] | AJ-Qual | Malawi | X | X | X | X | - | - | X | The prevalence of malaria was significantly correlated with meteorological and environmental parameters, such as the average quarterly atmospheric temperature, rainfall irregularities, normalised difference vegetative index (NDVI), and usage of the Rapid Diagnostic Test (RDT) for diagnosis. Unlike rainfall anomalies, which were linked to malaria prevalence just three months earlier, in the study, temperatures in the present month and each of the three months prior demonstrated an important connection with the illness occurrence. The lake and Shire Valley regions of Malawi have comparatively high risk, according to |

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|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | anticipated exposure levels. |
| Corell and Betsill (2017) [13] | AJ-Qual | International | X | X | X | X/- | - | X | X | NGOs influence international environmental negotiations on climate and desertification. NGOs engage in various activities, including lobbying, information-sharing, and advocacy. NGOs bridge gaps between states and citizens, shaping policy outcomes. |
| Crate and Nuttall (2016) [14] | AJ-Qual | International | X | X | X/- | X | X/- | X | X | Anthropology provides insights into human responses to climate change. Anthropological research highlights diverse perspectives, local knowledge, and adaptation strategies. Anthropologists contribute to policy-making by understanding the cultural dimensions of climate change. |
| Dessler and Parson (2019) [17] | AJ-Qual | International | X | X | X | - | X/- | X | X | The climate change debate involves both scientific and political aspects. Climate sceptics challenge scientific consensus, creating policy complexities. Understanding the science-politics interaction is crucial for effective climate action. |
| Dunlap and Brulle (2015) [19] | AJ-Qual | Uk | X | X | X/- | - | - | X | X | Sociological perspectives reveal societal responses to climate change. Cultural factors, values, and political ideologies shape climate change opinions. Understanding sociological dynamics can inform effective climate communication. |
| Dai *et al*., (2015) [16] | AJ | International | X | X | X | X | X | X | - | Wind energy has environmental benefits, but associated issues need consideration, environmental impacts include bird mortality, noise, and visual disturbance, and effective planning and technology can mitigate wind energy's negative effects. |
| Fang *et al*.,(2018) [20] | AJ-Qual survey | China | X | X | X | X | - | X | X | Climate change impacts China's ecosystems, affecting carbon sequestration. Human activities influence carbon dynamics and ecosystem services. Mitigation and adaptation strategies are needed to address these impacts. |
| Goodstein Polasky (2017) | AJ-PC | USA | X | X/- | X | - | X | X | - | Economics plays a role in shaping environmental policies and decisions. Economic valuation can help quantify environmental benefits and trade-offs. Balancing economic growth with environmental protection is a policy challenge. |
| Hayes *et al*. (2018) | AJ-Qual survey | International | X | X | X | X | - | X | X | Climate change impacts mental health, leading to increased anxiety and distress, and vulnerable populations are more susceptible to mental health effects, recognizing and addressing mental health impacts is crucial in climate policies. |
| Lan *et al*.,(2013) | AJ | China | X | X | X | X | - | - | X | The amount of time (estimated in dates) that the air pollution considered appropriate proved crucial for enhancing public health. Prospective regulations should strive to prolong the periods when the air purity is favourable whilst limiting or reducing the amount of harmful pollutants in the air. |
| Liu *et al*., (2015) [33] | AJ-Qual | China | X | X | X | X | - | - | X | The findings verified that pollution from the environment has major negative effects on public health, mostly in Central and Western China, and that periods of reasonably good air quality appear to be especially crucial for enhancing the health |

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|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | of the general population. Excellent air standard is also advantageous to well-being. |
| Lee *et al*. (2015) [28] | AJ-Qual survey | International | X | X | X | X/- | - | X/- | X | Public awareness and risk perception of climate change vary globally. Socioeconomic factors influence climate change awareness. Understanding these factors can inform effective communication strategies. |
| Levy and Patz (2015) [30] | AJ-Qual | International | X | X | X | X | - | X | X | Climate change impacts human rights and social justice. Vulnerable populations suffer disproportionately from climate impacts. Policies must address equity and justice in climate adaptation and mitigation. |
| Martienz *et al*. (2022) | AJ-Qual | European | X | X | X | X | - | X | X | Heat-health action plans are critical for protecting health during heatwaves. Regional and national policies vary in addressing heat-related health risks. Lessons from different countries can inform effective heat health planning. |
| Maccauley and Heffron (2018) [34] | AJ-Qual | International | X | X | X/- | X/- | - | X | X | Just transition frameworks promote equitable climate policies. Energy transition must consider social and economic impacts on communities. Just transition principles guide policies for workers and affected regions. |
| O'Brien *et al*., (2018) [36] | AJ-Qual | International | X | X | X | X | - | X | X | Youth activism contributes to climate change awareness and action. Youth-led movements influence public discourse and policies. Youth engagement is essential for sustainable development and climate action. |
| Franchini & Mannucci (2015) [22] | AJ | International | X | X | X | X | - | - | X | Climate change affects human health through multiple pathways, vulnerable populations are at higher risk due to environmental changes, and health systems need to prepare for climate-related health impacts. |
| Owusu and Asumadu-sarkodie 2016 [38] | AJ | International | X | X | X | X | X | X | - | Renewable energy sources are crucial for climate change mitigation. Sustainable energy options reduce carbon emissions and environmental impacts. Renewable energy technologies need policy support for adoption. |
| Salmond *et al*., (2016) [42] | AJ-PC | International Urban ecosystem | X | X | X | X | X/- | X | X | Urban street trees provide health-related ecosystem services. Green infrastructure improves air quality, temperature regulation, and mental well-being. Urban planning should prioritize nature-based solutions for health benefits. |
| Smith *et al*., (2019) [44] | AJ-Qual | Canada | X | X | X | X | - | X/- | X | The study deduces the environment has a cumulative effect on the spread of bacteria and that variables other than climate affect interprovincial bacterial prevalences. |
| Shepherd (2020) [43] | AJ | International | X | X | X | X | - | X | X | The capability generation framework offers a lens for vulnerability and resilience. Vulnerability results from limited capability to address climate impacts. Integrating capability considerations into policy enhances climate resilience. |
| Spaargaren (2020) [45] | AJ-P | International | X | X | X | X | X | X | X/- | Dietary changes can provide health and climate co-benefits. Plant-based diets have lower environmental impacts and health benefits, and Policy actions can promote sustainable diets for both health and climate goals. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Steul *et al*., (2018) [47] | AJ-Quan | Frankfurt | X | X | X | X | - | X | X | Heatwaves have mortality impacts, particularly in urban areas, Vulnerable populations are at higher risk during extreme heat events, and health policies should focus on prevention and risk communication. |
| Tietenberry *et al*., (2018) [49] | AJ | International | X | X | X | X/- | - | X/- | X | Environmental and natural resource economics contribute to policy analysis, Economic tools help assess trade-offs between development and environmental protection. Policy solutions involve considering economic incentives and environmental goals. |
| Watts *et al*., (2015) [51] | AJ | International | X | X | X | X | X | X | X | Climate change poses significant health risks and threats globally, vulnerable populations are disproportionately affected by climate impacts, and policies should integrate public health considerations into climate responses. |
| Watts *et al*., 2021 [52] | AJ-P | International | X | X | X | X | X | X | - | The Lancet Countdown emphasizes converging health and climate crises, Urgent actions are needed to address climate impacts on health, and Policymakers must prioritize health and climate for a sustainable future. |
| Winker *et al*., (2020) | AJ-Qual | International | X/- | X/- | - | - | - | X | - | Health impact assessments play a role in policy development, Global health impact assessment practices vary in scope and methodology and, a comprehensive approach considers multiple dimensions of health and environment. |
| Wright and Nyberg (2017) [54] | AJ | Australia | X | X/- | X | - | - | X/- | - | Organizations often resist major changes in response to climate change, Business-as-usual practices hinder transformative actions, and recognizing organizational dynamics is crucial for promoting sustainability. |
| Woodward, *et al*.,(2019) [53] | AJ | China | X | X | X | X | - | X | X | There are clear parallels in China's efforts to minimise regional contaminants in the atmosphere: restrictions on the combustion of coal have led to improved local quality of air and enhanced healthcare. However, there may be additional health dangers, contingent on how regulations are put into place as well as what protections are in place. |
| Yaka *et al*., (2008) [55] | AJ-Qual | Burkina Faso and Niger | | | | | | - | X | connections connecting environment as well as Meningococcal meningitis demonstrated that the wintertime environment, with its amplified Harmattan hurricanes, appears to play a role regarding the disease's recurrence in Niger and Burkina Faso. |
| Tenias *et al*., (2015) | AJ-Qual | Spain | X | X | X | X | - | - | X | Hip fracture rates showed an annual rise of 1.5% in the upland region, while an autumnal rise of 9% was detected in the Mediterranean area in the fall and winter months compared to the summer. The incidence of hip fractures was highly correlated with the environment particularly wind: days with higher wind speeds and/or fewer windy periods were linked to an increase in hip fracture incidence of 44% in the hinterland but 51% in the region around the Mediterranean. |

Keys: (AJ-Qual) Academic Journal Qualitative, (AJ-Quan) Academic Journal Quantitative, (AJ-PC) Academic Journal Professional communication, (PJ) Periodic Journal, (X): Adequately addressed, (-) Not addressed, (X/-): partially addressed

## Supplement 5

**Table 4**: Discussion summary of the study findings

| Section | Summary | Key References (as requested) |
|---|---|---|
| Environmental / Climate Change | Climate change, driven by human activities like burning fossil fuels, causes severe weather events and fosters the spread of infectious diseases. The Eco-Health Theory and Conceptual Model explain the environmental-health links. | Fang *et al*. (2018) [20], IPCC (2021), Levy & Patz (2015) [30], O'Neil (2017) [37], Clayton & Karsia (2020) [11], Patz *et al*. (2015) [30] |
| Direct Health Effects | Extreme events like heatwaves and floods cause immediate health issues (heatstroke, respiratory diseases). Urban heat islands and air pollution worsen health outcomes. | O'Brien *et al*. (2018) [36], Goodstein & Polasky (2017) [24], Raza *et al*. (2019) [41], Liu *et al*. (2015) [33] |
| Indirect Health Effects | Climate disrupts food systems, increases malnutrition, alters disease vector patterns, and heightens mental health issues through migration and disasters. | O'Brien *et al*. (2018) [36], Clayton (2020) [11], Bryson *et al*. (2021) [5], Wright & Nyberg (2017) [54], Tietenberg & Lewis (2018) [49], Goodstein & Polasky (2017) [24] |
| Health Impact of Climate Change | Heat-related illnesses, vector-borne diseases, respiratory issues, waterborne diseases, malnutrition, and mental health issues are rising. Socioeconomic inequalities exacerbate vulnerabilities. | Urry (2015) [50], Smith *et al*. (2019) [44], Dunlap & Brulle (2015) [19], Dessler & Parson (2019) [17], Amadi *et al*. (2018) [1], Lilienfeld *et al*. (2018) [32], Franchini & Mannucci (2015) [22], Owusu *et al*. (2016) [38], Crate & Nuttall (2016) [14], Dai *et al*. (2015) [16], Springmann *et al*. (2016) [46], Lewis & Tietenberg (2019) [31] |
| Regional Disparities and Vulnerable Populations | Marginalized communities bear the heaviest burden. Factors like socioeconomic status, age, gender, and indigenous status shape vulnerabilities. | Bullard (1990); Levy & Patz (2015) [30]; Lilienfeld *et al*. (2018) [32]; Shepherd & Dissart (2022) [43]; Collins *et al*. (2015); Watts *et al*. (2021) [52] |
| Regional Disparities | Low-income countries face greater impacts due to weak infrastructure. Disease patterns shift with climatic changes, even affecting developed countries. | Doyle (2016) [18], Crate & Nuttall (2016) [14], Tenías *et al*. (2015), Dessler & Parson (2019) [17], Chirombo *et al*. (2020) [10], Lewis & Tietenberg (2019) [31], Owusu & Asmadu-Sarkodie (2016) [38], Calthorpe (2015) [6] |
| Population Disparities | Low-income, minority groups, and gender minorities face compounded risks. Epidemics like meningitis and malaria correlate with climatic factors. | Correll & Betsill (2017) [13], Monroe *et al*. (2019) [35], Ayanlade *et al*. (2020) [4], Yaka *et al*. (2008) [55] |
| Gender Dynamics | Women face higher health risks from waterborne diseases and gender-based violence during disasters. Intersectionality intensifies vulnerabilities. | Salmond *et al*. (2016) [42], UN Women (2020) [5], Carter *et al*. (2015) [8] |
| Age Groups | Children and elderly are highly vulnerable to climate-related health impacts like diarrheal diseases, heat stress, and respiratory illnesses. | Dai *et al*. (2015) [16], Parajuli *et al*. (2019) [39], Crate & Nuttall (2016) [14], Tietenberg & Lewis (2018) [49] |
| Policy Responses and Effectiveness Assessment | Integrated, multi-level, adaptive policies are critical. Health and climate goals should align under frameworks like SDGs. | Carney (2015) [7], Monroe *et al*. (2019) [35], Lee *et al*. (2015) [28], Watt *et al*. (2018), Kraft (2021) [26], Dessler & Parson (2019) [17], Dunlap & Brulle (2015) [19], Carter (2018) [9] |
| Existing Policy Frameworks | Integrated approaches (e.g., Paris Agreement, One Health) and national strategies (e.g., Sweden) show promise. Health co-benefits justify climate action. | Clayton (2020) [11], Raza *et al*. (2019) [41], Andersson & Keskitalo (2018) [2], Goodstein & Polasky (2017) [24], McCauley & Heffron (2018) [34], O'Brien *et al*. (2018) [36] |
| Health Co-benefits and Mitigation | Policies like cycling infrastructure improve both health and reduce emissions. Careful design needed to avoid negative trade-offs. | Clayton & Karazsia (2020) [11], Woodward *et al*. (2019) [53], UNEP (2018) |
| Equity Considerations | Climate policies must prioritize marginalized communities for fair adaptation and mitigation outcomes. | O'Neill (2017) [37], Levy & Patz (2015) [30], O'Brien *et al*. (2018) [36] |
| Disaster Risk Reduction | Integrating health and disaster risk frameworks (e.g., Sendai Framework, Kerala's disaster plan) strengthens resilience. | Fang *et al*. (2018) [20], Watts *et al*. (2015) [51], Carney (2015) [7] |
| Conclusion | Climate change and health are inseparable. Integrated, adaptive, and equity-focused policies are vital for resilient public health systems. | Carney (2015) [7] |

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