Received: 30 January 2020 | Revised: 9 November 2020 | Accepted: 16 November 2020

DOI: 10.1002/wcc.696

FOCUS ARTICLE

WIREs CLIMATE CHANGE WILEY

How climate change interacts with inequity to affect nutrition

Leah Salm[1,2] | **Nicholas Nisbett**[1] | **Laura Cramer**[3,4] | **Stuart Gillespie**[2] | **Philip Thornton**[3,4]

[1]Institute of Development Studies (IDS), Brighton, UK

[2]International Food Policy Research Institute (IFPRI), Washington, District of Columbia

[3]CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS), Nairobi, Kenya

[4]International Livestock Research Institute (ILRI), Nairobi, Kenya

Correspondence
Leah Salm, Institute of Development Studies (IDS), Brighton, UK.
Email: l.salm@ids.ac.uk

Funding information
CGIAR Research Program on Agriculture for Nutrition and Health (A4NH); CGIAR Research Program on Climate Change; Agriculture and Food Security (CCAFS)

Edited by Lars Otto Naess, Domain Editor, and Mike Hulme, Editor-in-Chief

Abstract

Climate change poses a growing threat to the achievement of optimal nutritional status, both directly through affecting food production and indirectly through altering social and economic influences in people's lives. These adverse nutrition outcomes are not evenly distributed across the world, and vulnerable populations are the most impacted. Understanding how different forms of inequity interact with climate change and adverse nutritional outcomes is a novel area of research in today's challenging environment of increased climate change pressures. This article presents the results of a systematic literature search undertaken to identify the connections, trends and pathways between climate change, inequity and nutrition outcomes. Forty-six peer-reviewed studies are identified that explore these complex interactions with a specific focus on the extent to which equity is a fundamental component of climate change and nutrition research. The pathways captured in this body of evidence are mapped to current framework thinking to identify trends and gaps. While there is a trend for studies to acknowledge an unfair distribution of vulnerability to adverse nutrition outcomes, there is less attention given to the (lack of) recognition of the social situations which increase these groups' vulnerability and the absence of representation or inclusion of these groups as vital decision-makers. Studies that do incorporate these core dimensions of equity take mixed-method and qualitative approaches. This highlights an inherent value in stepping outside the usual scope of empirical climate change research, one that incorporates the voices of those most affected.

This article is categorized under:

Climate and Development > Sustainability and Human Well-Being

KEYWORDS

climate change, equity, nutrition, systematic review

1 | INTRODUCTION

In recent years, evidence and projections of climate change impacts on food and nutrition security have increased significantly. Notable among the many publications are those of the Intergovernmental Panel on Climate Change (IPCC), several Lancet Commissions on climate change and planetary health (2009–2015), and the 2018 Lancet Countdown on Health and Climate Change. They all provide authoritative and compelling projections of the major human health effects of climate change, many of which relate to effects on food and nutrition security.

That the climate crisis will not be felt equally is well-recognized—it will continue to increase food insecurity and undernutrition among vulnerable populations in many low and middle-income countries (LMICs) via several pathways including reduced food production, increased likelihood of crop failure and extreme weather events that produce droughts and flooding, increased food-borne and other infectious diseases, and civil disorder (IPCC, 2018, 2019). Climate change will affect all forms of malnutrition, not just undernutrition. While severe food insecurity and hunger are associated with lower obesity prevalence, mild to moderate food insecurity is paradoxically associated with higher obesity prevalence among vulnerable populations (Swinburn et al., 2019).

As well as being affected by climate change, agriculture—as a leading source of greenhouse gas (GHG) emissions—contributes to climate change. The relationship is bi-directional. As national wealth grows, so does the rate of urbanization with associated shifts toward motorized transportation, reduced physical activity, higher prevalence of obesity, and higher GHG emissions (Egger, Swinburn, & Islam, 2012). Diet is changing too, especially among urban groups, with increased consumption of ultra-processed food and beverages, beef and dairy products, whose production is associated with high GHG emission intensities (Gill, Feliciano, Macdiarmid, & Smith, 2015).

There are growing concerns about the way in which climate change is affecting patterns of inequity and inequality (Roy et al., 2018). Transnational and intergenerational inequality is being exacerbated (Watts et al., 2018). The impacts of climate change are likely to be most severe on populations, communities, and households who are least capable of adapting to them (Levy & Patz, 2015). These groups are also those with the lowest carbon footprint per person. They contribute least to the crisis but are likely to suffer most from its effects. People will experience climate change differently not only because of where they live, but because of who they are—because they grew up in poverty, or because of their perceived race, gender, caste, ethnicity, age, sexuality, or disability (Reckien et al., 2017). It is hard to justify these inequalities simply on the basis of geography or identity. In defining equity, therefore, we echo the WHO Commission on Social Determinants of Health in arguing that "Where systematic differences in health are judged to be avoidable by reasonable action they are, quite simply, unfair. It is this that we label health inequity" (CSDH, 2008).

The objective of this review article is two-fold. First, we seek to build on the conceptual work linking climate change to nutrition outcomes through the integration of three essential equity dimensions (fairness, justice, and inclusion), and the creation of our own climate change and nutrition "meta-framework." Second, through mapping primary research in this area, we aim to see how equity is considered, the depth in which is it conceptualized, and how research trends map to our meta-framework. Ultimately, through this work, we seek to inform the design and implementation of climate change-related policies and programs aimed at adaptation and mitigation so that they equitably address nutrition challenges.

The article is organized as follows: the next section lays out our conceptual framework and describes how we created the meta-framework we use in our analysis. We describe our methods in Section 3, followed by descriptive results and pathway findings in Section 4. Section 5 presents our discussions of the findings and addresses the gaps we see in the currently available literature, while our recommendations for improving the research agenda on climate change, equity, and nutrition are presented in the concluding section.

2 | CONCEPTUAL FRAMEWORK

Through this decade, a significant amount of work has been done on conceptualizing pathways and links between climate change and nutrition. Though a combination of scoping internet searches, snowballing, and citation tracking we identified many such frameworks (Bryan et al., 2017; Crahay et al., 2010; Fanzo, Mclaren, Davis, & Choufani, 2017; FAO, IFAD, UNICEF, WFP, & WHO, 2018; Mckune et al., 2015; Smith et al., 2014; Thomson & Fanzo, 2015; Tirado et al., 2013; UNICEF, 2011; Watts et al., 2018; WHO, 2016). We found a high degree of overlap between frameworks. For example, many utilized the longstanding UNICEF, 1990 conceptual framework of drivers of malnutrition as the structure onto which climate considerations were applied. What we found to be lacking across these frameworks

however was a consideration of inequity as a significant modifying factor between climate change pathways and nutrition outcomes. We sought to build upon such conceptual frameworks by incorporating equity considerations as a core component.

The exercise of identifying frameworks was valuable in itself as we found equity considerations to be lacking in the conceptual literature. In the context of this review, the framework also serves as a template onto which we can map the findings in order to get a sense of which pathways are prominent in the captured research. This is an adapted approach of the "Best Fit Framework Synthesis" model (Carroll, Booth, Leaviss, & Rick, 2013) which can be defined as a common sense approach to identify and a priori framework/frameworks against which to code data extracted from included studies, and then use analysis of that extracted data and/or thematic analysis to improve the framework, identify new themes, unexplored pathways or other data gaps.

We merged three frameworks which we found to accurately represent the climate and nutrition science as well as the broader social science analysis of equity to create our own "meta-framework" (Figure 1). The choice of these frameworks was based on detailed comparison of identified frameworks and discussion among the article authors, which included representation of experts on climate change, public health nutrition, equity, and international development. The first framework we used was the 2018 Lancet Countdown on health and climate change report (Watts et al., 2018), and the second was the UNICEF framework that highlights various drivers of nutrition outcomes at different levels (UNICEF, 1990, subsequently adapted for the Lancet Nutrition Series e.g., Black et al., 2013). The third framework builds on a recent article on climate and equity (Karlsson, Naess, Nightingale, & Thompson, 2018), which itself builds on a more substantial theoretical base on equity (see Harris & Nisbett, 2018), drawing particularly on work of the political philosopher John Rawls (Rawl, 1972) and feminist scholars such as Nancy Fraser (Fraser, 2011).

This meta-framework is one-directional as it was the cumulative effect of these pathways on the nutrition outcomes of the vulnerable that informed our research questions. However, there are many ways in which the layers of the framework can further perpetuate the threat of climate change via various multi-directional relationships within levels and through feedback loops. While they are out of the scope of this review, they are very important and deserve acknowledgement. For example, dietary intake, particularly the growing demand for meat and dairy in emerging economies, is fundamentally changing the scale of agricultural production and is a significant contributor to GHG emissions. Additionally, the way that vulnerable groups respond to the pressures of climate change may result in damaging coping behaviors. For example, deforestation and land degradation are short-term means of overcoming shocks, but with long-term impacts of increasing vulnerability and intensity of future shocks (IPCC, 2012). Another consideration is how mitigation and adaptation policy impact the most vulnerable, as there is potential for leaving these hard-to-reach groups behind, or even worse, doing more harm (Hasegawa et al., 2018; Nelson et al., 2009), leading to calls in the climate and equity literature for a more "just transition" to low carbon economies (Markkanen & Anger-Kraavi, 2019).

2.1 | Equity conceptualization

Equity is often mistaken with equality of outcomes, but a substantial literature has highlighted the fact that while studies of equity are predominantly concerned with the fact of such inequalities, they are *as* concerned or in some cases *more* concerned with the processes which led to those unequal outcomes in the first place (Harris & Nisbett, 2018). These may have deep roots, work in the field of health equity and the social determinants of health has advocated going beyond simple causes to the "causes of causes" (CSDH, 2008; Marmot, 2007). To draw on such nuanced conceptions of equity in our framework, we developed three concepts which extend and deepen a focus on equity, based on the forms of equity ("distributional," "recognition," and "procedural") highlighted by Karlsson et al., 2018. We adapt these concepts to make them accessible to a wider audience[1] labeling them: fairness, justice, and inclusion—as described below.

2.1.1 | Fairness

At their most basic, health inequities can be judged via differences in the distribution of health outcomes, or access to services or program coverage. That these differ according to socio-economic status—whether by wealth, gender, age, disability, sexuality and so on, highlights some of the "causes of causes" at play. In systematic reviews, the

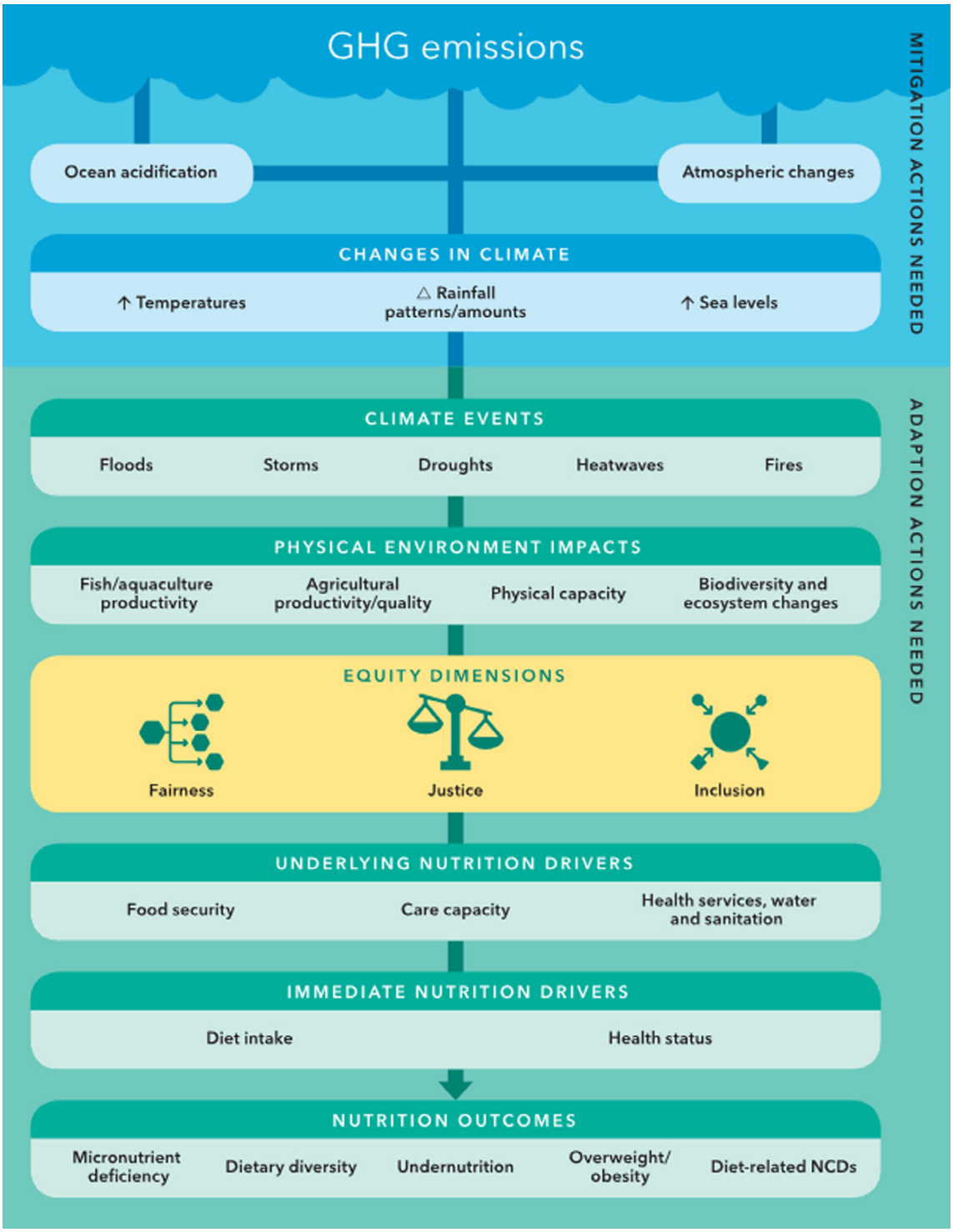

FIGURE 1 Climate change and nutrition meta-framework. Meta-framework maps the impacts of climate change on malnutrition. The pathways pass through an essential equity dimension which mediates nutrition outcomes. Δ, variable; NCD, noncommunicable disease

PROGRESS+ methodology has been developed to help search for and analyze health impacts of such difference (Box 1). Building on this, the concept of fairness (which has otherwise been referred to as distributional equity—Karlsson et al., 2018), focuses on the equitable distribution of outcomes, or access to services, or life chances, regardless of one's geography or identity. Fairness also references the need to ensure both equitable distribution of costs or impacts, as well as both positive and negative outcomes of climate-related policy.

BOX 1. PROGRESS+ EQUITY THEMES

PROGRESS+ was developed as a tool within systematic reviews to give explicit consideration to equity in the design of health interventions. It is now widely applied beyond interventions and provides useful (evidence-based) categories to guide equity analysis and data extraction. It is now a deep-rooted component of systematic reviews, incorporated by Cochrane, and the Campbell group, among others. Representing the multi-dimensionality of the distribution of health outcomes, it is a flexible tool that allows further categories to be added, depending on the given topic.

P	Place of residence
R	Race/ethnicity/culture/language
O	Occupation/livelihood
G	Gender
R	Religion
E	Education
S	Socioeconomic status/poverty
S	Social capital
+	+ Personal characteristics (age, disability, sexual orientation, etc)

2.1.2 | Justice

Fairness overlaps with the concept of justice, but justice (as in our legal systems) suggests a need to understand how these inequalities occurred in the first place and to provide some means of redressal. As the WHO definition suggests, people experience poor health outcomes not only because there is some natural or biomedical mechanism causing the outcome, but because of the policy, political, and social decisions that inadequately allocate scarce resources to people based on their identity in the first place. These resources might be education, or food, or wealth, or might be access to both preventative and curative health services and medicine. Furthermore, these inequities in resource allocation do not occur purely by chance but can reflect wider stigma and discrimination in society which can take place over generations. Justice implies that these inequities need to be recognized before they can be acted on (recognition equity (Karlsson et al., 2018)) and that different people's values and beliefs need to be taken into account in such action.

2.1.3 | Inclusion

The concept of inclusion (also referred to as process equity—Karlsson et al., 2018) focuses on who is involved in decision making, or processes of governance and accountability: who is accountable to whom. Decision-making and governance processes are equitable not just when they pay attention to inequitable processes, but when those most affected by decisions are adequately represented in them in the first place (or as disability and other counter-discrimination advocates have stated memorably "nothing about us, without us"[2]). Table 1 provides some illustrative examples of how each concept relates to climate change.

3 | METHODS

A systematic mapping approach was undertaken as this proved flexible to accommodate the broad range of health, social, and environmental science literatures. The aim of a systematic mapping review is not to answer a specific question (as is the norm in a systematic review), rather, the aim is to collate, describe catalogue available evidence, while upholding rigorous and transparent processes of capturing relevant evidence. (James, Randall, & Haddaway, 2016). A systematic search was undertaken to identify relevant peer-reviewed research published between 2007 and 2019.

TABLE 1 Equity concepts and examples

	Fairness	Justice	Inclusion
Description	Distribution of causes, outcomes, costs, or benefits (including of attempted policy solutions) differing by socio-economic category (e.g., the PROGRESS+ categories)	Norms, beliefs, institutions via which inequity occurs or is perpetuated over time	Representation in different forms of decision making, particularly of groups listed in PROGRESS+ categories (including policy processes at local, national and international levels, democratic fora including local councils or traditional forms of government, civil society strengthening, national parliaments, global institutions).
Examples	1. Agricultural productivity effects are greater on poorer groups, greater still on those with poor market access, and/or in ecologically geographically marginal areas. (outcomes) 2. Lack of access of particular socio-economic groups to goods and services known to shape nutritional pathways (e.g., health services, social protection, and decent employment) (causes) 3. Mitigation measures such as land use management having costs locally for particular groups in terms of land access that were not anticipated in policy (policy effects)	1. Gender/patriarchy/ assumptions about women's roles, work caring practices, and so on. 2. Racism, policy/political/ resource favoritism of particular ethnic majority groups, or traditional holders of power 3. Regard or disregard for forms of locally held beliefs, knowledge, and practices (e.g., agricultural practices)	1. Participatory planning in climate adaptation initiatives 2. Strengthening parliamentary or local council representation of minority groups

The year 2007 was chosen as the cut-off date as it was around this time that the IPCC were in the process of making conceptual linkages between climate change and nutrition that have been built on in all assessment reports since then (IPCC, 2007).

The review team has diverse collective expertise in nutrition, social science, climate change and adaptation science, and risk and vulnerability analysis, which is very valuable in this interdisciplinary approach. A search syntax was created using the Population Exposure Comparison Outcome (PECO) model, with input from all reviewers into these terms (L. S., L. C., N. N., P. T., S. G.; Tables 2 and 3). Scoping searches were trialed in several databases to gauge the depth and relevance of published material. Search terms were further refined as a result, for example dropping terms that "exploded" results with irrelevant studies. A protocol was drafted following the scoping phase, however, due to the updated guidelines of the PROSPERO review registry, this review did not fit the criteria for review registration. Given the *mapping* nature of this review and type of evidence synthesis, this is unlikely to impact the reliability of our findings.

The final search was completed on January 15, 2019, in the PubMed, Web of Science and CABI abstracts databases. These databases were selected due to their interdisciplinary content and relevance across social science, health, and environmental fields. Search terms were adapted slightly for each database to reflect differing database search features. Search results were imported into the bibliographic software Mendeley and duplicates were excluded (Figure. 2). The remaining studies ($n = 5{,}304$) were screened by title and abstract against predetermined eligibility criteria to determine relevance (Table 2). Two authors (L. S. and L. C.) completed the screening, each screened 2,562 studies, those deemed potentially includable were screened a second time by the alternate reviewer to ensure consistency in inclusion. Discrepancies were discussed and, where relevant, expert opinion was sought from the rest of the review team (N. N., P. T., and S. G.). A total of 320 studies were screened at a full-text level by LS and LC. Reasons for exclusion of studies were recorded, and 46 studies were determined to fully meet the inclusion criteria.

Only peer-reviewed primary research was included.[3] Beyond this, no further quality assessment of included studies was completed. Citations of included literature can be found in Supporting Information Item 2. The following information was extracted from the studies; country, region, study design, climate change components, nutrition outcomes, pathways of interaction, and sources of inequity (using the PROGRESS + themes). Two additional categories were added to PROGRESS+ that were relevant to the literature retrieved, that were not captured within original categories.

TABLE 2 Eligibility criteria for included research

Include	Exclude
Population/problem	
• Nutrition of human populations • Must include climate change related events/hazards/variability • Study must relate one off events (e.g., Flood, drought) to the context of climate change more broadly	• Studies reporting on nutrition of animals/livestock/crop production only (not relating it to human nutrition outcomes) • Studies that report one off events (flood, drought, and wildfire) with no connection to the context of climate change
Exposure	
• Studies must report on at least one dimension of inequity/vulnerability **PROGRESS+** can be used to frame groupings of inequity **P**lace of residence **R**ace/ethnicity/culture /language **O**ccupation **G**ender **R**eligion **E**ducation **S**ocioeconomic status **S**ocial capital **+** personal characteristics (age, disability), features of relationships, time dependent relationships • Additional equity factors not captured in the PROGRESS+ categories	• Studies that do not report/differentiate vulnerable groups or consider equity dimensions in their reporting
Comparison/control	
• Studies do not need to report a comparison/control groups.	• N/A
Outcome	
• Must report on nutrition specific outcomes	• Studies reporting on broader underlying factors only (and do not report nutrition outcome). For example, studies reporting on food security, diarrhea, and sanitation only
Setting	
• All regions	• N/A
Study design	
• Peer-reviewed literature • Primary research	• Reviews • Commentaries • Gray literature • Books
Language	
• English, Spanish, and French	• All other languages
Date of publication	
• Date: Studies/reports published after January 1st, 2007	• Studies published prior to 2007

These were enabling environment factors (weak governance, access to credit, provision of health insurance, country food import capacity, diminishing food aid) and climate change specific factors (unavailability of early warning systems, low adaptive capacity).

3.1 | Equity scoring of included studies

To enable a deeper understanding of how inequity is conceptualized in the literature, the studies were further assessed in relation to the three equity dimensions presented in Table 1. A scoring system was applied in order to differentiate studies with a strong focus on each of the equity dimensions, from those that just touched on them, or did not address

TABLE 3 Search syntax

Terms	Syntax
Climate change terms	"climat* change" OR" changing climate" OR "climate variability" OR "global warming" OR "climate shock*" OR "environmental change" OR "extreme climate" OR "extreme weather" OR "weather extreme" OR "climate extreme" OR "CO2 concentration*" OR "GHG emission*"
AND	
Equity terms	equity OR equitable OR inequit* OR equality OR inequality OR marginalized OR marginalization OR marginalize OR marginalise OR marginalised OR marginalization OR empower* OR disempower* OR vulnerable OR vulnerabilit* OR slum OR poverty OR impoverished OR race OR ethnicity OR ethnic OR culture OR indigenous OR refugee OR minorities OR gender OR religion OR poor OR "resource poor" OR "social capital" OR "social exclusion" OR "sexual orientation" OR morbidity OR disability OR disabled OR disparity OR deprivation OR deprived OR urban OR rural OR lowland* OR "market access" OR coastal OR highland* OR "land access" OR "rural growth" OR (infrastructure and access) OR caste OR tribe OR tribal OR wealth OR "pro-poor" OR "income gap" OR high-income OR low-income OR higher-income OR lower-income OR "social norm" OR "social change" OR "social behaviour" OR "socio-economic" OR elder OR elderly OR geriatric OR youth OR "young people" OR adolescen* OR power OR ((gender OR woman* OR women OR "man" OR "men" OR female OR male OR girl* OR boy*) and (equal* OR inequal* OR equit* OR inequit* OR dispar* OR *empower*))
AND	
Nutrition terms	stunting OR wasting OR "low birth weight" OR anemia OR malnutrition OR undernutrition OR overweight OR obesity OR hunger OR emaciation OR marasmus OR "nutritional status" OR undernourished OR nutrition OR anthropometry OR "noncommunicable disease" OR "cardiovascular disease" OR diabetes OR overnutrition OR overnourished

these dimensions at all. The articles were read in full and the content assessed to see if/how dimensions of fairness, justice, and inclusion were incorporated. Each dimension received a score from 0 to 3, with 0 indicating no incorporation at all, 1 indicating some acknowledgement of the equity dimension but not in detail, 2 indicating that the article considered the dimension in a more thorough sense (albeit not as a core theme explored/measured), and 3 indicating that exploring the dimension was a fundamental objective of the research and/or measured in the methodology. Therefore, the maximum score is 9, indicating comprehensive integration of all three equity dimensions.

This scoring system was not designed to reduce studies to a numerical value, or as a means of quality assessment. Nor was it designed as a critique of individual studies. Its purpose rather was to unpack the treatment of equity across a body of work that had already passed through a comprehensive search and eligibility screening process, satisfying the criterion of an equity focus within the context of climate change and malnutrition. While it is imperfect (given the overlap between dimensions and gray areas that cannot easily be captured within the three concepts), it does serve as a three-dimensional lens through which we can consider how equity is conceptualized and reported, helping to reveal trends and gaps in research.

4 | RESULTS

4.1 | General characteristics

The included articles ($n = 46$) covered a range of regions, although the greatest coverage was of sub-Saharan Africa ($n = 19$; Table 4).

The majority of articles focused on undernutrition in their evaluation of how climate change affects nutrition outcomes (Table 4). When we look at nutrition outcomes investigated by the region of study, we see that the overwhelming focus in sub-Saharan Africa is on undernutrition, while diet-related noncommunicable diseases (NCDs) have only been included in articles focusing on North America, South Asia and East Asia and Pacific (Figure 3). The two articles that examined global trends focused on micronutrient deficiency (Myers, Wessells, Kloog, Zanobetti, & Schwartz, 2015; Nelson et al., 2018). Only one article included the potential for climate change to impact obesity (McIver et al., 2016).

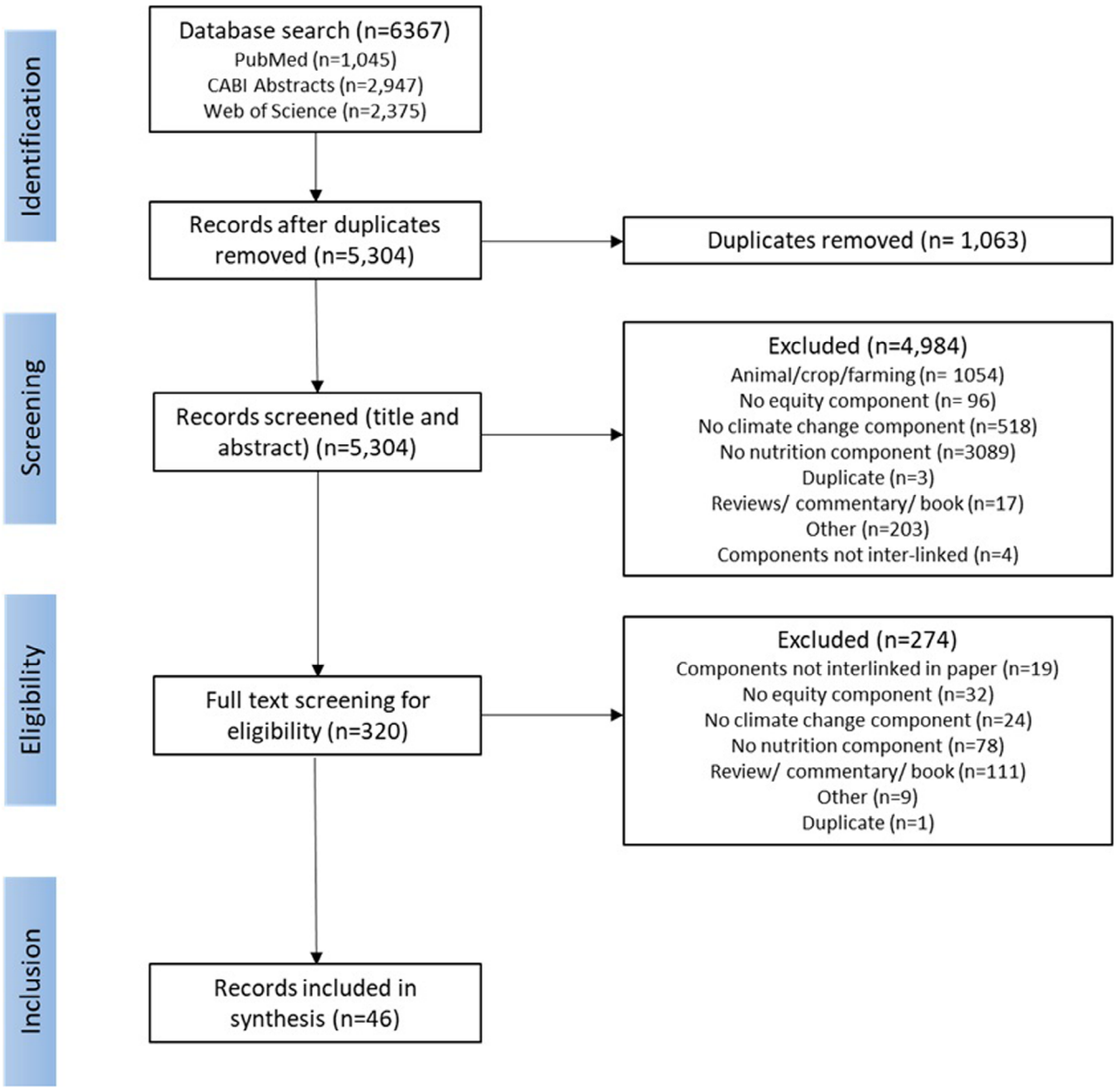

FIGURE 2 PRISMA flowchart of search results. Figure illustrates the number of studies captured in search process and the reasons for exclusion of irrelevant studies

The two most commonly addressed climate change components in the included articles were rainfall variability and temperature variability. In some cases, particularly those articles using scenario modeling to evaluate potential future impacts, the climate change components were not specified and were addressed in general terms as undefined effects of climate change.

Using the PROGRESS+ framework to identify factors that affect equity, we categorized the literature by the factors discussed in each article. Place of residence and socioeconomic status were the most frequently included categories, followed by occupation/livelihood and specific personal characteristics (children, women, single motherhood, and morbidity; Figure 4). Although religion is a category within the PROGRESS+ framework, none of the articles included it in their analyses. Despite gender becoming a more frequent consideration within studies on climate change, agriculture and nutrition, only a small number of included articles in this review addressed gender as an equity component. Further details of examples within each category can be found in Supporting Infornation Item 1.

TABLE 4 General characteristics

General characteristics	No. of studies
World Bank geographic regions	
Sub-Saharan Africa	19
South Asia	12
East Asia and Pacific	9
North America	8
Latin America and the Caribbean	3
Europe and Central Asia	2
Global	2
Middle East and North Africa	1
Nutrition outcomes	
Undernutrition	32
Diet quality/diversity	9
Micronutrient deficiency	7
Diet-related NCDs	5
Overweight/obesity	1
Climate change component	
Temperature variability	20
Rainfall variability	19
Drought	11
Flooding	10
General/undefined climate change	5
Sea level rising	4
Extreme weather event	3
Sea ice melting	3
Co2 emissions	3
Typhoon/cyclone	2
Snow/ice/wind variation	1
Landslide	1
PROGRESS+ equity themes	
Place of residence	23
Race/ethnicity/culture/language	12
Occupation/livelihood	15
Gender	4
Religion	—
Education	4
Socioeconomic status	18
Social capital	1
+ Personal characteristics	12
+ Enabling environment	9
+ Climate specific	5

4.2 | Equity dimensions and scoring

On reviewing the scores (0–3) within the three categories of fairness, justice, and inclusion, we find a high level of variation of scores across studies and their characteristics (Figure 5). Nine articles scored highly across all three dimensions

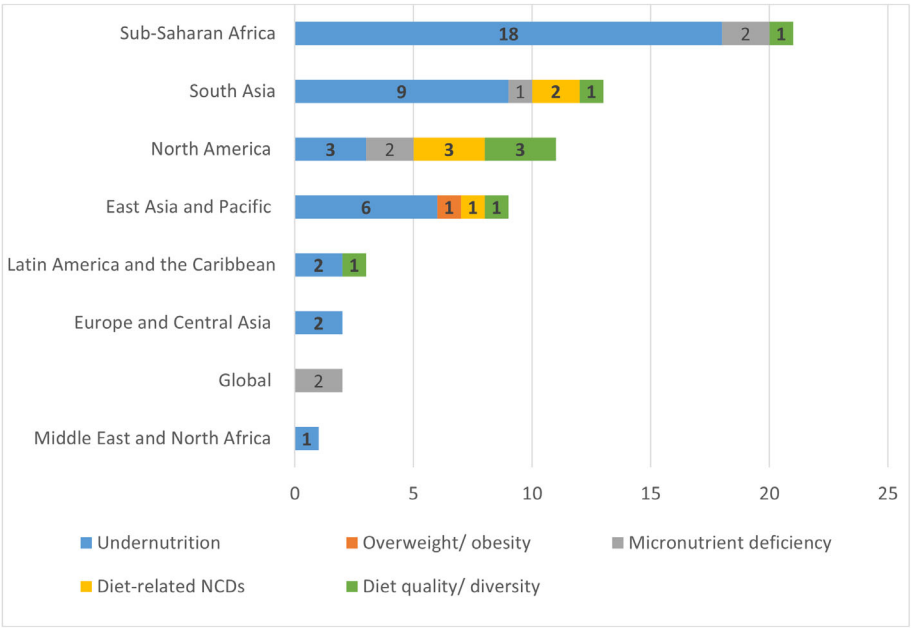

FIGURE 3 Nutrition outcomes reported across regions. Some studies report more than one nutrition outcome or region therefore total is greater than 46 (number of included studies)

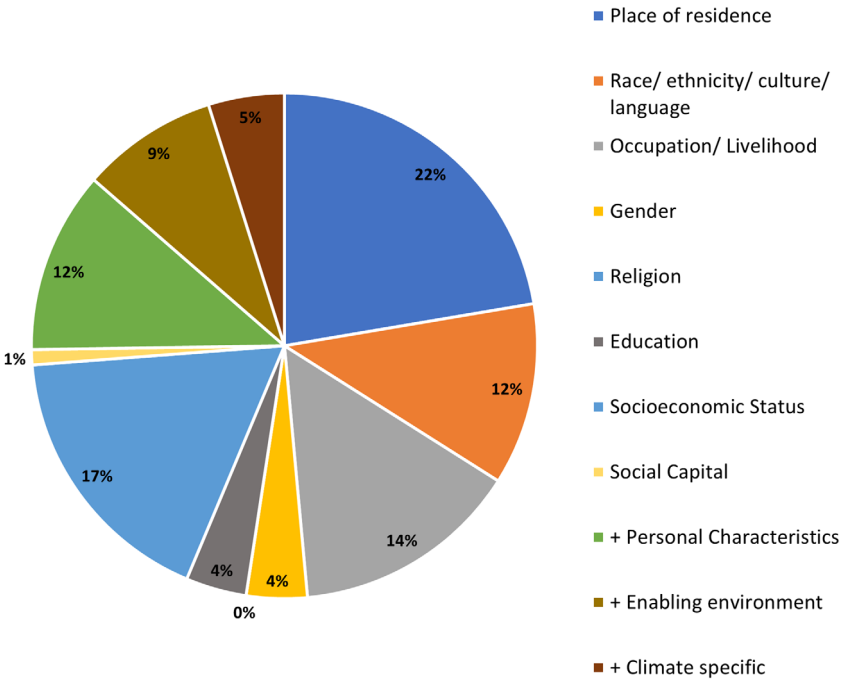

FIGURE 4 PROGRESS+ equity themes in included studies

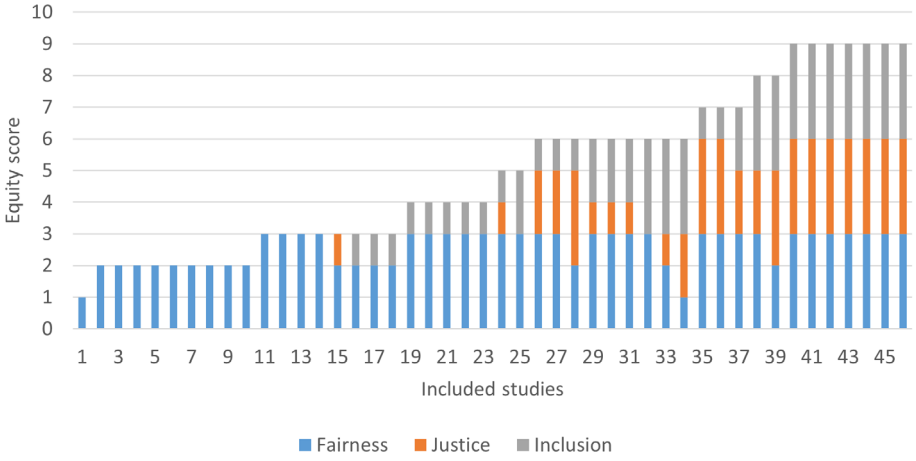

FIGURE 5 Equity scores ranked from lowest to highest for each included article. Each article can score a maximum of 3 per equity dimension (fairness, justice, and inclusion), therefore a maximum score of 9

(total score of 8 or 9) and are all either qualitative or mixed methods studies. Of the nine highest scoring articles on equity, four are focused on North America, three on Africa, and three on East Asia/Pacific/South Asia.[4] The articles that scored lowest on equity are modeling, cross-sectional, and other quantitatively focused studies. Articles score highest in the fairness dimension (mean score 2.6 out of maximum 3), lowest on the justice dimension (mean score of 1.0) and low on the inclusion dimension (mean score of 1.3).

4.3 | Framework pathways

To relate the articles included in the systematic review to the meta-framework we created through our framework scoping exercise, we identified the pathways described in each article and mapped these to our framework (Figure. 6).

Figure 6 illustrates the pathways identified in the included literature, from changes in climate to nutrition outcomes. Each vertical black bar represents a component that mirrors those in our meta-framework. The length of each black bar represents the volume of literature reporting on that component. Not all studies pass through each layer, therefore when there is missing information, this is represented with an asterisk.

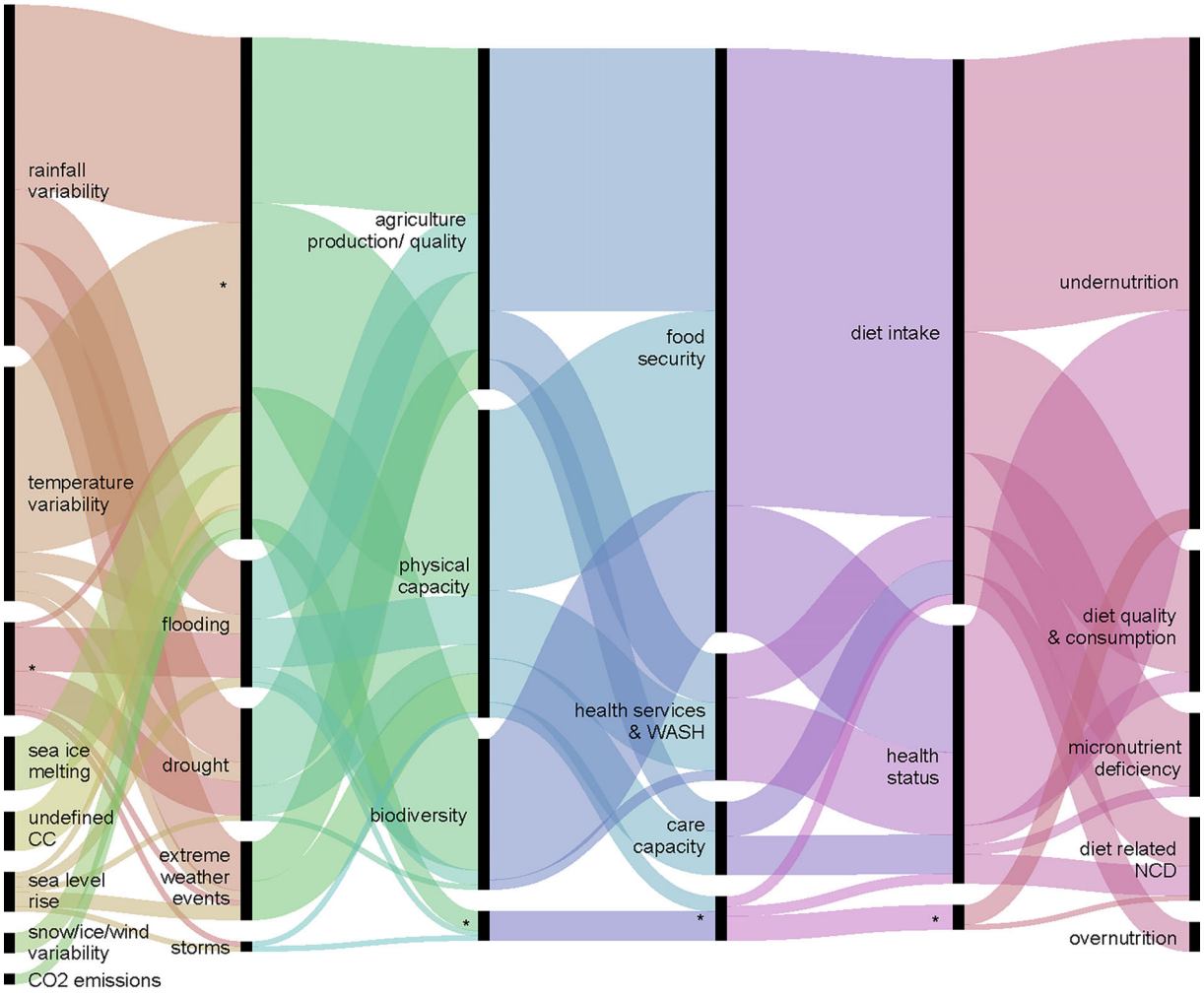

FIGURE 6 Pathways of interaction from climate change to nutrition outcomes. CC, climate change; NCD, noncommunicable disease; WASH, water, sanitation, and hygiene, *, some studies do not pass through each category of the pathway. When there is missing information this is represented with an asterisk. Each vertical black bar represents a component that mirrors those in the meta-framework. The length of each black bar represents the volume of literature reporting on that component

Food security is the most widely reported pathway component, with over half of studies identifying this route from climate change to nutrition outcomes. We see that agricultural productivity and quality, physical capacity, and biodiversity all feed into food security. From the element of food security, dietary intake is studied most of all, ultimately leading to undernutrition as the main nutrition outcome reported (this includes stunting, wasting, underweight, thinness, low birth weight, and hunger). It is perhaps unsurprising to find this dynamic within the literature given the highly researched links between food security in the face of climate change and the ultimate impacts on food availability and quality. What is more nuanced about this pathway is the equity score across each dimension. Of the articles reporting on this pathway, the average score for fairness is 2.4, justice is 1.0, and inclusion is 1.3, giving an overall average equity score of 4.7 (out of 9). We see a trend of scoring highly in the identification of the distribution of fairness, with lower scores for recognizing how and why this exists and/or is perpetuated.

While the food pathway is well represented, we found a dearth of articles that met our criteria and that consider the ways climate change is affecting the underlying nutrition drivers of care capacity and health services, water, and sanitation. Dietary intake and undernutrition are the most common driver and outcome within the pathways examined, but this leaves a research gap around health status as an immediate driver and other nutrition outcomes (micronutrient deficiency, dietary diversity, overweight/obesity, and diet-related NCDs) in the context of how climate change is affecting nutrition.

No included articles examined the effects that climate change is having on fish or aquaculture productivity and which might affect nutrition outcomes despite this sector being very important to nutrition, especially among marginalized populations in many countries (Harper, Zeller, Hauzer, Pauly, & Sumaila, 2013; Lynch et al., 2016).

5 | DISCUSSION

Our analysis highlights four key lessons. First, we have identified a body of literature that explores the connections between climate change and malnutrition, mediated by some form of inequity, whether that be due to place of residence, occupation, gender, and so on. Through the application of equity scores across the articles included in our review, we find strong evidence of the inequitable distribution (fairness) of nutrition outcomes in the context of climate change. This is to be expected, as the search strategy and eligibility criteria were developed to identify such equity issues. However, when interrogated further to investigate the reasons (or "causes of the causes") for the perpetuation of discrimination (justice) overtime or the processes of exclusion or inclusion of vulnerable groups, the equity score of literature drops considerably. Thus, while we have evidence of that distribution of inequity in the context of climate change, we find much less evidence exploring how and why this inequity persists. This is an important gap: without this evidence, it becomes much harder to identify (let alone implement) equitable adaptation and mitigation solutions that are appropriate to the needs and struggles of populations vulnerable to climate change. A paucity of evidence exploring the inclusion of vulnerable groups as a process in decision making highlights another key gap in the research, particularly in the context of inclusive policy solutions.

Marginalized, or at-risk groups have often sustained generations of entrenched disadvantage due to systemic discriminatory systems (whether they be racial, patriarchal, colonial, and capitalist). Securing of land tenure rights for indigenous peoples is one such example of how inclusion can improve their legitimacy as stakeholders and decision-makers, as well as play a vital role in climate change mitigation. "Secure tenure rights for indigenous groups provides a foundation for stewardship of fragile natural resources and development of innovative and equitable partnerships for the protection and restoration of tropical forests and other natural carbon sinks and the biodiversity they support." (Quan & Dyer, 2008). Furthermore, allocating productive assets such as land tenure rights in the name of women can enhance their tenure security and allow more benefits to flow to their dependants (Mitchell & McEvoy, 2019), improve economic independence of women, investment in child education, and smaller family size (Atinc et al., 2005), which are well understood underlying drivers of malnutrition (Black et al., 2013).

Second, the studies that score highly across the three dimensions we considered indicate the value of using qualitative or mixed methods in their analysis. In the nine studies that scored highly with an 8 or 9, the equity categories of gender and race, ethnicity, culture, and language are well represented, with an above-average representation compared with all the studies. The high-scoring gender studies ($n = 4$) detail factors such as women skipping meals to feed other family members in times of hunger, traveling further for water and fuel, and lacking access to productive resources and assets as sources of heightened vulnerability to poor nutrition outcomes (Adebo & Sekumade, 2013; Alston & Akhter, 2016; Ford & Beaumier, 2011; Githinji & Crane, 2014). The high-scoring studies exploring race, ethnicity,

culture, and language largely focus on Inuit communities across North America, the way their lifestyles are changing due to melting ice patterns, and how this affects their mobility, traditional ways of hunting and fishing, and ultimately their diets (Ford & Beaumier, 2011; Wesche & Chan, 2010).

Such observations suggest the need for a holistic perspective, coupled with appropriate research methods that are capable of delving into the different dimensions that communities face. The articles that score the lowest on equity were modeling, cross-sectional, or other quantitatively-focused studies. This is not a criticism of these individual studies, as there is a time and place for research that models and estimates the impacts of climate change on health outcomes. However, if/when we are looking for evidence on the inequities facing vulnerable groups, and if the majority of evidence that is returned focuses on quantitative modeling studies that do not delve into deeper considerations of equity, then we have a problem as the solutions we choose will likely respond to this distributional understanding on equity, rather than investigating how and why it emerged in the first place.

There is increased recognition of the need to reshape the type of data we gather, and how it is collected. This is prioritized in the 2020 Global Nutrition Report which calls for the disaggregation of health and nutrition data for equity determinants such age, sex, ethnicity, education, wealth, disability, migration status, and geographic location, as well as qualitative data collection at the community level to increase understanding of their root causes (GNR, 2020). Participatory methods have been a development research tool that has the potential to shift the power dynamics when telling the stories of marginalized groups and co-create solutions. There is evidence of these methods in practice bringing success in climate adaptation and mitigation projects (Figueiredo & Perkins, 2013). However, caution is needed to ensure that longstanding power struggles and hierarchies are not reinforced by having every stakeholder around the same table, Sprain (2017) argues that there are specific paradoxes to participation in climate governance that need careful consideration.

Third, our analysis highlights that the existing literature is highly skewed toward a consideration of only one of many possible pathways from climate change impacts to nutrition outcomes: from direct effects on agricultural productivity through to food insecurity and thence to reduced dietary intake and undernutrition. This is undoubtedly a critically important pathway, but others may be equally important. We find few articles that meet our inclusion criteria addressing the ways in which climate change affects nutrition through underlying drivers other than food security such as care capacity and health services, water, and sanitation. This constitutes another major gap concerning health status as a driver of nutrition outcomes, particularly in the context of impeded physical capacity and stress. We found very few studies reporting in on obesity and diet-related NCDs.

It is important to note that additional articles were captured in our original search that linked increases in obesity to contributions to GHG emissions and climate change (e.g., Goodman et al., 2012; Squalli, 2014), but these were excluded from our review because, as noted in the conceptual framework section, we did not focus on that feedback loop in this research. The one included article reporting on obesity (McIver et al., 2016) discusses the likelihood of climate change affecting the local production of nutritious foods among Pacific Island nations and the potential increased reliance on imported, processed foods contributing to an increased prevalence of overweight and obesity. Such changes are not the result of individual choices but reflect rapidly changing food environments—a nutrition transition—which is influenced by a range of commercial drivers such as advertising, marketing, product formulation and lobbying of government policy (Friel et al., 2016). Such "commercial determinants" have been documented as influencing the available policy space both for food and healthy eating, as well as the climate crisis (Swinburn et al., 2019). In LMICs, such trends reflect a longer history of imbalanced trade stretching back to the colonial era, with fresh foods such as fruit in particular flowing one way toward wealthier countries and poorer countries a growing market for more unhealthy, processed products (Baker, Friel, Schram, & Labonte, 2016; Hawkes, 2010; Huang, 2010; Lopez, Loopstra, McKee, & Stuckler, 2017). Trade and food policy therefore can contribute to inequity in nutrition outcomes, as well as perpetuate climate damage. When food is considered a commodity, rather than essential for health, there is a proliferation of unhealthy and unsustainable foods (Thow & Nisbett, 2019).

Fourth, our review highlights the complexity and heterogeneity of the linkages between climate change and nutrition outcomes. The disciplinary mix of our author team is a good illustration: our analytical framework was developed as a result of collective expertise in nutrition, social science, climate change and adaptation science, and risk and vulnerability analysis. The value of inter- and multi-disciplinarity in this kind of research, when allied with the need for qualitative or mixed analytical methods, may partially explain the dearth of literature that explores the whole gamut of pathways between climate change and nutrition outcomes and the concentration on what the problem is rather than why the problem exists: such research can be time-consuming, challenging to manage, and potentially costly.

6 | CONCLUSIONS

Addressing the root causes of inequity can help mediate the negative impacts of climate change on nutrition outcomes. Our research indicates that inequity is most often considered in terms of the unfair distribution of vulnerability. But, we are missing a trick: in this era of sustainable development, lack of knowledge on fundamental justice, and the inclusion dimensions of equity, may severely limit the extent to which sustainable solutions to the challenges posed by climate change can be identified and implemented effectively. This is an important gap to fill if we are to broaden our understanding of deep-rooted inequities and how to reorient research and resources for equitable adaptation and mitigation action. One concrete step toward filling this gap is to develop a more sophisticated analytical framework than the one we developed here. The relationships between GHG emissions, climate, the physical environment, equity, different nutrition drivers, and ultimate nutrition outcomes are not linear. They include multiple feedback loops, as well as temporal and spatial dependencies. Improved understanding of these relationships could greatly enhance the frameworks and tools that could be brought to bear to identify equitable climate action. A second step is to embrace the need for inter- and multi-disciplinary teams in planning and implementing research in this arena, despite the undoubted challenges. Third, it is critical to share these findings and their implications with policymakers who are in a place to take action and enact plans and strategies that can help mitigate the inequitable effects of climate change on nutrition among populations vulnerable to these impacts.

ACKNOWLEDGMENTS

The authors wish to thank Ms. Ciara Gillespie for her assistance in extracting data from the full text of included articles, and Mr. Jason Chow for his design expertise in creating our Climate Change and Nutrition Meta Framework. This work was implemented as part of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), which is carried out with support from CGIAR Fund Donors and through bilateral funding agreements. For details please visit https://ccafs.cgiar.org/donors. The views expressed in this document cannot be taken to reflect the official opinions of these organizations. Production of this article was also undertaken as part of the CGIAR Research Program on Agriculture for Nutrition and Health (A4NH).

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

AUTHOR CONTRIBUTIONS

Leah Salm: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing-original draft; writing-review and editing. **Nicholas Nisbett:** Conceptualization; formal analysis; funding acquisition; investigation; methodology; project administration; resources; supervision; validation; writing-original draft; writing-review and editing. **Laura Cramer:** Conceptualization; data curation; formal analysis; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing-original draft; writing-review and editing. **Stuart Gillespie:** Conceptualization; funding acquisition; investigation; methodology; supervision; writing-original draft; writing-review and editing. **Philip Thornton:** Conceptualization; formal analysis; funding acquisition; methodology; supervision; visualization; writing-original draft; writing-review and editing.

ORCID

Leah Salm https://orcid.org/0000-0001-6488-3322
Nicholas Nisbett https://orcid.org/0000-0002-9558-2263
Laura Cramer https://orcid.org/0000-0003-1559-3497
Stuart Gillespie https://orcid.org/0000-0002-8501-5943
Philip Thornton https://orcid.org/0000-0002-1854-0182

ENDNOTES

[1] Conceptual development is based on work undertaken by NN, with Jody Harris and Phillip Baker, in preparation for the 2020 Global Nutrition Report.

[2] See for example, European Disability Federation: http://www.edf-feph.org/.

[3] As a team, we discussed including gray literature and the potential value this would add to the review. We decided to exclude nonpeer-reviewed materials, along with review and commentary pieces, as it was felt that these materials often reiterate the findings of peer-reviewed empirical work that is already published.

[4] One article looks at both North America and East Asia/Pacific by studying immigrants from the Marshall Islands to the US.

FURTHER READING

IPBES. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat.

Watts, N., Adger, W. N., Ayeb-Karlsson, S., Bai, Y., Byass, P., Campbell-Lendrum, D., ... Costello, A. (2017). The lancet countdown: Tracking progress on health and climate change. *Lancet*, *389*, 1151–1164. https://doi.org/10.1016/S0140-6736(16)32124-9

Thomas, K., Hardy, R. D., Lazrus, H., et al. (2019). Explaining differential vulnerability to climatechange: A social science review. *WIREs Clim Change*, *10*, e565. https://doi.org/10.1002/wcc.56518of18THOMASETAL.

Woroniecki, S., Krüger, R., Rau, A.-L., et al. (2019). The framing of power in climate change adaptation research. *WIREs Clim Change*, *10*, e617. https://doi.org/10.1002/wcc.617.

Hughes, S., Hoffmann, M. (2020). Just urban transitions: Toward a research agenda. *WIREsClim Change*, *11*, e640. https://doi.org/10.1002/wcc.640HUGHESANDHOFFMANN11.

Explaining differential vulnerability to climatechange: A social science review. https://doi.org/10.1002/wcc.56518.

The framing of power in climate change adaptation research https://doi.org/10.1002/wcc.617

Just urban transitions: Toward a research agenda https://doi.org/10.1002/wcc.640

REFERENCES

Adebo, G. M., & Sekumande, A. B. (2013). Climate change and adaptive capacity of women to rural water supply in ekiti state nigeria. *Academic Research International*, *4*(2), 386–399.

Alston, M., & Akhter, B. (2016). Gender and food security in Bangladesh: The impact of climate change. *Gender, Place & Culture*, *23*, 1–15. https://doi.org/10.1080/0966369X.2016.1204997

Atinc, T. M., Banerjee, A., Ferreira, F. H., Lanjouw, P., Menendez, M., Ozler, B., ... Woolcock, M. (2005). *World development report 2006: Equity and development*. Washington, DC: World Bank Group.

Baker, P., Friel, S., Schram, A., & Labonte, R. (2016). 2016, trade and investment liberalization, food systems change and highly processed food consumption: A natural experiment contrasting the soft-drink markets of Peru and Bolivia. *Globalization and Health*, *12*(1), 1.

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., de Onis, M., ... Uauy, R. (2013). Maternal and Child Nutrition Study Group,. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet*, *382*, 427–451. https://doi.org/10.1016/S0140-6736(13)60937-X

Bryan, E., Theis, S., Choufani, J., De Pinto, A., Meinzen-Dick, R., & Ringler, C. (2017). *Gender-sensitive, climate-smart agriculture for improved nutrition in Africa south of the Sahara in: A thriving agricultural sector in a changing climate: Meeting Malabo declaration goals through climate-smart agriculture*. Washington DC: International Food Policy Research Institute. https://doi.org/10.2499/9780896292949_09

Carroll, C., Booth, A., Leaviss, J., & Rick, J. (2013). "Best fit" framework synthesis: Refining the method. *BMC Medical Research Methodology*, *13*, 37. https://doi.org/10.1186/1471-2288-13-37

Crahay, P., Mitchell, A., Gomez, A., Israël, A. D., Salpeteur, C., Mattinen, H., Deret, H., Lapegue, J., Grosjean, L., Aissa, M. A., Brown, R., Swan, S. H., Pietzsch, S. & Dufour, C. (2010). The threats of climate change on undernutrition—A neglected issue that requires further analysis and urgent actions. *SCN News*, pp. 4–10

CSDH. (2008). *Closing the gap in a generation: Health equity through action on the social determinants of health. Final report of the commission on social determinants of health*. Geneva: World Health Organization.

Egger, G., Swinburn, B., & Islam, F. M. A. (2012). Economic growth and obesity: An interesting relationship with world-wide implications. *Economics and Human Biology*, *10*, 147–153. https://doi.org/10.1016/j.ehb.2012.01.002

Fanzo, J., Mclaren, R., Davis, C., & Choufani, J. (2017). *Climate change and variability: What are the risks for nutrition, diets, and food systems?* Washington DC: International Food Policy Research Institute.

FAO, IFAD, UNICEF, WFP & WHO. (2018). *The state of food security and nutrition in the world 2018. Building climate resilience for food security and nutrition*. Rome: FAO.

Figueiredo, P., & Perkins, P. E. (2013). Women and water management in times of climate change: Participatory and inclusive processes. *Journal of Cleaner Production*, *60*, 188–194. https://doi.org/10.1016/j.jclepro.2012.02.025

Ford, J.D., & Beaumier, M. (2011). Feeding the family during times of stress: experience and determinants of food insecurity in an Inuit community. *The Geographical Journal*, *177*(1), 44–61. http://dx.doi.org/10.1111/j.1475-4959.2010.00374.x.

Fraser, N. (2011). Feminism, capitalism, and the cunning of history. *Cahiers du Genre*, *50*, 165–192. https://doi.org/10.3917/cdge.050.0165

Friel, S., Ponnamperuma, S., Schram, A., Gleeson, D., Kay, A., Thow, A.-M., & Labonte, R. (2016). Shaping the discourse: What has the food industry been lobbying for in the trans Pacific partnership trade agreement and what are the implications for dietary health? *Critical Public Health*, *26*, 518–529. https://doi.org/10.1080/09581596.2016.1139689

Gill, M., Feliciano, D., Macdiarmid, J., & Smith, P. (2015). The environmental impact of nutrition transition in three case study countries. *Food Security*, *7*, 493–504. https://doi.org/10.1007/s12571-015-0453-x

Githinji, V., & Crane, T. A. (2014). Compound vulnerabilities: The intersection of climate variability and HIV/AIDS in Northwestern Tanzania. *Weather Climate Society*, *6*, 9–21. https://doi.org/10.1175/WCAS-D-12-00052.1

Global Nutrition Report. (2020). *Action on equity to end malnutrition*. Bristol, UK: Development Initiatives.

Goodman, A., Brand, C., Ogilvie, D., & iConnect consortium. (2012). Associations of health, physical activity and weight status with motorised travel and transport carbon dioxide emissions: A cross-sectional, observational study. Environ. *Health*, *11*, 52. https://doi.org/10.1186/1476-069X-11-52

Harper, S., Zeller, D., Hauzer, M., Pauly, D., & Sumaila, U. R. (2013). Women and fisheries: Contribution to food security and local economies. *Marine Policy*, *39*, 56–63. https://doi.org/10.1016/j.marpol.2012.10.018

Harris, J. & Nisbett, N. (2018). Equity in social and development-studies research: Insights for nutrition. *UNSCN News*, pp. 57–63.

Hasegawa, T., Fujimori, S., Havlík, P., Valin, H., Bodirsky, B. L., Doelman, J. C., ... Witzke, P. (2018). Risk of increased food insecurity under stringent global climate change mitigation policy. *Nature Climate Change*, *8*, 699–703. https://doi.org/10.1038/s41558-018-0230-x

Hawkes, C. (2010). The influence of trade liberalisation and global dietary change: The case of vegetable oils, meat and highly processed foods. In C. Hawkes, C. Blouin, S. Henson, N. Drager, & L. Dubé (Eds.), *Trade, food, diet and health: Perspectives and policy options*. Oxford: Wiley-Blackwell.

Huang, S. (2010). Global trade of fruits and vegetables and the role of consumer demand. In C. Hawkes, C. Blouin, S. Henson, N. Drager, & L. Dubé (Eds.), *Trade, food, diet and health: Perspectives and policy options*. Oxford: Wiley-Blackwell.

IPCC. (2007). *Climate change 2007: Synthesis report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva, Switzerland: IPCC.

IPCC. (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of Working Groups I and II of the intergovernmental panel on climate change*, Cambridge, UK and New York, NY: Cambridge University Press.

IPCC. (2018). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.

IPCC (2019). Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.

James, K. L., Randall, N. P., & Haddaway, N. R. (2016). A methodology for systematic mapping in environmental sciences. *Environmental Evidence*, *5*, 7. https://doi.org/10.1186/s13750-016-0059-6

Karlsson, L., Naess, L. O., Nightingale, A., & Thompson, J. (2018). "Triple wins" or "triple faults"? Analysing the equity implications of policy discourses on climate-smart agriculture (CSA). *Journal of Peasant Studies*, *45*, 150–174. https://doi.org/10.1080/03066150.2017.1351433

Levy, B. S., & Patz, J. A. (2015). Climate change, human rights, and social justice. *Annals of Global Health*, *81*, 310–322. https://doi.org/10.1016/j.aogh.2015.08.008

Lopez, A. M., Loopstra, R., McKee, M., & Stuckler, D. (2017). Is trade liberalisation a vector for the spread of sugar-sweetened beverages? A cross-national longitudinal analysis of 44 low-and middle-income countries. *Social Science & Medicine.*, *172*, 21–27.

Lynch, A. J., Cooke, S. J., Deines, A. M., Bower, S. D., Bunnell, D. B., Cowx, I. G., ... Beard, T. D. (2016). The social, economic, and environmental importance of inland fish and fisheries. *Environmental Reviews*, *24*, 115–121. https://doi.org/10.1139/er-2015-0064

Markkanen, S., & Anger-Kraavi, A. (2019). Social impacts of climate change mitigation policies and their implications for inequality. *Climate Policy*, *19*, 827–844. https://doi.org/10.1080/14693062.2019.1596873

Marmot, M. (2007). Achieving health equity: From root causes to fair outcomes. *Lancet*, *370*, 1153–1163. https://doi.org/10.1016/S0140-6736(07)61385-3

McIver, L., Kim, R., Woodward, A., Hales, S., Spickett, J., Katscherian, D., ... Ebi, K. L. (2016). Health impacts of climate change in Pacific Island countries: A regional assessment of vulnerabilities and adaptation priorities. *Environmental Health Perspectives*, *124*, 1707–1714. https://doi.org/10.1289/ehp.1509756

Mckune, S. L., Borresen, E. C., Young, A. G., Auria Ryley, T. D., Russo, S. L., Diao Camara, A., ... Ryan, E. P. (2015). Climate change through a gendered lens: Examining livestock holder food security. *Global Food Security*, *6*, 1–8. https://doi.org/10.1016/j.gfs.2015.05.001

Mitchell, D., & McEvoy, D. (2019). Land Tenure and Climate Vulnerability. *UN-HABITAT*, *3*. https://unhabitat.org/sites/default/files/documents/2019-06/un-habitat-gltn-land-and-climate-vulnerability-19-00693-web.pdf

Myers, S., Wessells, K., Kloog, I., Zanobetti, A., & Schwartz, J. (2015). Effect of increased concentrations of atmospheric carbon dioxide on the global threat of zinc deficiency: A modelling study. *The Lancet Global Health*, *3*, e639–e645. https://doi.org/10.1016/S2214-109X(15)00093-5

Nelson, G., Bogard, J., Lividini, K., Arsenault, J., Riley, M., Sulser, T. B., ... Rosegrant, M. (2018). Income growth and climate change effects on global nutrition security to mid-century. *Nature Sustainability*, *1*, 773–781. https://doi.org/10.1038/s41893-018-0192-z

Nelson, G., Rosegrant, M. W., Koo, J., Robertson, R., Sulser, T., Zhu, T., ... Lee, D. (2009). *Climate change: Impact on agriculture and costs of adaptation*. Washington, DC: IFPRI. https://doi.org/10.2499/0896295354

Quan, J. & Dyer, N. (2008). *Climate change and land tenure: The implications of climate change for land tenure and land policy*. Food and Agriculture Organization Land Tenure Working Paper 2, International Institute for Environment and Development and Natural Resources Institute, University of Greenwich.

Rawl, J. (1972). *A theory of justice*. Cambridge, MA: Harvard University Press.

Reckien, D., Creutzig, F., Fernandez, B., Lwasa, S., Tovar-Restrepo, M., Mcevoy, D., & Satterthwaite, D. (2017). Climate change, equity and the sustainable development goals: An urban perspective. *Environment and Urbanization*, *29*, 159–182. https://doi.org/10.1177/0956247816677778

Roy, J., Tschakert, P., Waisman, H., Abdul Halim, S., Antwi-Agyei, P., Dasgupta, P., ... Suarez Rodriguez, A. G. (2018). Sustainable development, poverty eradication and reducing inequalities. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, et al. (Eds.), *Global warming of 1.5°C. an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Geneva, Switzerland: IPCC. In Press.

Smith, K. R., Woodward, A., Campbell-Lendrum, D., Chadee, D. D., Honda, Y., Liu, Q., ... Sauerborn, R. (2014). Chapter 11 human health: Impacts, adaptation, and co-benefits. In *Climate change 2014: Impacts, adaptation, and vulnerability. Part a: Global and sectoral aspects*. Cambridge, United Kingdom and New York: Cambridge University Press.

Sprain, L. (2017). Paradoxes of public participation in climate change governance. *The Good Society*, *25*, 62–80. https://doi.org/10.5325/goodsociety.25.1.0062

Squalli, J. (2014). Is obesity associated with global warming? *Public Health*, *128*, 1087–1093. https://doi.org/10.1016/j.puhe.2014.09.008

Swinburn, B. A., Kraak, V. I., Allender, S., Atkins, V. J., Baker, P. I., Bogard, J. R., ... Dietz, W. H. (2019). The global Syndemic of obesity, undernutrition, and climate change: The lancet commission report. *Lancet*, *393*, 791–846. https://doi.org/10.1016/S0140-6736(18)32822-8

Thomson, M., & Fanzo, J. (2015). *Climate change and nutrition. Global nutrition report 2015: Actions and accountability to advance nutrition and sustainable development*. Washington, DC: International Food Policy Research Institute.

Thow, A. M., & Nisbett, N. (2019). Trade, nutrition, and sustainable food systems. *Lancet*, *394*, 716–718. https://doi.org/10.1016/s0140-6736(19)31292-9

Tirado, M. C., Crahay, P., Mahy, L., Zanev, C., Neira, M., Msangi, S., ... Müller, A. (2013). Climate change and nutrition: Creating a climate for nutrition security. *Food and Nutrition Bulletin*, *34*, 533–47.10.1177/156482651303400415.

UNICEF. (2011). *Children and climate change: The impacts of climate change on nutrition and migration affecting children in Indonesia*. Bangkok: UNICEF East Asia and Pacific Regional Office (EAPRO).

UNICEF. (1990). *Strategy for improved nutrition of children and women in developing countries*. New York: United Nations Children's Fund.

Watts, N., Amann, M., Ayeb-Karlsson, S., Belesova, K., Bouley, T., Boykoff, M., ... Costello, A. (2018). The lancet countdown on health and climate change: From 25 years of inaction to a global transformation for public health. *Lancet*, *391*, 581–630. https://doi.org/10.1016/S0140-6736(17)32464-9

Wesche, S. D., & Chan, H. M. (2010). Adapting to the impacts of climate change on food security among Inuit in the Western Canadian Arctic. *EcoHealth*, *7*, 361–373. https://doi.org/10.1007/s10393-010-0344-8

WHO, (2016). El Niño and Health Global Overview. https://www.who.int/hac/crises/el-nino/who_el_nino_and_health_global_report_21jan2016.pdf

How to cite this article: Salm L, Nisbett N, Cramer L, Gillespie S, Thornton P. How climate change interacts with inequity to affect nutrition. *WIREs Clim Change*. 2021;12:e696. https://doi.org/10.1002/wcc.696