frontiers | Frontiers in Climate

TYPE Review
PUBLISHED 11 April 2025
DOI 10.3389/fclim.2025.1549686

OPEN ACCESS

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RECEIVED 21 December 2024
ACCEPTED 12 March 2025
PUBLISHED 11 April 2025

CITATION
Turner M, Rice AM, Fornof E and Ribot J (2025) Putting migration in context: a review of how theory and methods shape climate-induced migration research findings. *Front. Clim.* 7:1549686. doi: 10.3389/fclim.2025.1549686

Putting migration in context: a review of how theory and methods shape climate-induced migration research findings

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Widespread media reports that climate change is driving international migration have led to an upsurge in research seeking to verify this phenomenon. In a methodological review of this research, we identified close to 3,000 studies referring to climate-induced emigration from Mesoamerica and West Africa and found only 102 that empirically evaluate the causal link. We analyze the causal inference implications of these 102 studies' methodological characteristics and how these are shaped by conceptual framing, data sources, and region. Cluster analysis identified three groups of studies based on conceptual framing—45 largely ignoring and 33 fully engaging with the context of migration decisions and vulnerabilities of those exposed to climate change, with 24 in between. Studies were also coded for how they incorporated key methodological features needed to support causal claims. We find that conceptual framings, choice of data, and data availability in each study region strongly influence the prevalence of basic causal inference problems (e.g., mismatched spatial and temporal scales, over-aggregation of migration data, lumping of destination types). A key feature of 'decontextual' studies is an over-reliance on weather-migration correlation. These approaches neglect the causal nexus surrounding migration, which involves many factors beyond those attached to weather but which may co-vary in certain instances. Such analyses are prone to spurious correlations and fail to address the specifics of who migrates in the face of climate change and why.

KEYWORDS

climate reductionism, causal inference, West Africa, Mesoamerica, scale, ecological fallacy, vulnerability

1 Introduction

Widespread journalistic accounts of climate-change induced international migration have raised welcomed attention to the damages of greenhouse gas emissions (Elliott, 2019; Ionesco et al., 2016; Miller, 2017). These accounts have coincided with a dramatic increase in scholarly analyses of the relationship between weather variability and emigration rates since 2015 (Maretti et al., 2019; Moore and Wesselbaum, 2022; Piguet, 2022). But, to what degree is this 'climate-migration crisis' actually caused by climate change? The rush to affirm the climate-migration connection can hide other causes, providing fertile ground for what Hulme (2011, 2023) calls 'climate reductionism'—the tendency to ignore other factors while fully attributing outcomes to climate change whenever weather might play a role. This reductionism hides the complexity of migration decisions and introduces potential causal-inference problems.

Social phenomena such as migration, as well as conflict, hunger, and economic losses, are increasingly viewed as outcomes of climate change. Yet, in migration studies, on which we focus,

rigorous empirical studies evaluating the causal relationship between climate parameters and migration are relatively rare compared to publications that invoke these relationships or treat them as common knowledge. A long history of migration research shows how complex migration decisions are—reflecting not only what some in the literature call 'push' factors like climate stress, but 'pull' factors such as the varied interests of migrants and their families, as well as the 'capabilities' of potential migrants to embark on migration journeys. Moreover, 'push' factors are multiple and interrelated, such as poverty and violence, making the clear assignment of causation difficult even by the most sophisticated of statistical techniques (Ribot, 2023, 1995). There is a complex causal nexus that surrounds migration; climate stresses are only one set of causal influences (Garip and Reed, 2025; Garni, 2010; Hamilton and Chinchilla, 1991; Neumann and Hermans, 2017; Tuholske et al., 2024).

We focus on Mesoamerica (Central America and Mexico) and West Africa (Sudano-Sahelian West Africa), two regions with long histories of internal and international migration and that have recently received significant global attention (Piguet et al., 2018) as source regions for the United States and Europe. Prior reviews of climate-induced migration research point to the different types of relationships found between weather parameters and migration (Borderon et al., 2019; Moore and Wesselbaum, 2022; Obokata et al., 2014; Šedová et al., 2021; White, 2011). These diverse findings may reflect not only different local situations but also causal inference problems stemming from research design and methods as has been argued by some (Gamlen et al., 2018; Henry et al., 2003; Perch-Nielsen et al., 2008; Lilleør and Van den Broeck, 2011). Rather than summarizing the findings of the many studies reviewed, we focus on reviewing their conceptual framings, data sources, and methodological characteristics. Unlike other methodological reviews (Beine and Jeusette, 2021; Bilsborrow and Henry, 2012; Hoffmann et al., 2021; Neumann and Hilderink, 2015; Piguet, 2022), we illuminate how conceptual framing and data sources can introduce causal inference problems. More specifically, we ask:

1. What are the different ways that climate vulnerability and migration decision-making are conceptualized and how do these conceptualizations co-vary?
2. What is the prevalence of different methodological characteristics of climate-induced migration studies (and which are prone to causal inference problems)?
3. How are these methodological features shaped by conceptual framing (1 above), data used, and region-specific emphases?
4. What is learned by this comparative review that could be used to improve future research on climate-induced migration?

We bring to the question of climate-induced migration a political ecology perspective that focuses on the material conditions that constrain rural livelihoods and how these material conditions are produced through both social and environmental change at multiple spatial and temporal scales. As such, we carefully consider prior work on the socioeconomic roots of migration while being attentive to how environmental changes influence resource-dependent rural societies. Political ecology developed out of a critique of hazards approaches that ignored vulnerability as the precondition to damages due to environmental changes (Watts, 1983). Instead, political ecologists analyze how the social responses to environmental change are shaped by the sociocultural and political-economic environments that predispose communities to loss or damage. As such, political ecology, using a critical realist approach (Sayer, 1992), has long grappled with questions of causal inference (Blaikie, 1985; Blaikie and Brookfield, 1987).

Our review shows that while many studies, following popular media accounts, seek to confirm that climate change is inducing migration from Mesoamerica and West Africa, most of these are biased by causal inference challenges facing empirical work in this realm. We begin by briefly describing the causal nexus that surrounds climate-induced migration followed by a discussion of methods and causal inference issues most pertinent to the study of climate-induced migration. Next are methods, results, and discussion sections. By attending to causal inference questions, this review identifies strengths and weaknesses of existing scholarship to form the basis for developing new approaches to climate-induced migration that are more inclusive of social causal relations.

2 Causal inference and approaches to climate-induced migration

We reviewed empirical research that seeks to identify the contribution of climate change to decisions to migrate. Communities are exposed to a changing climate in a myriad of different ways with only a segment of the community choosing to migrate. Statistical analyses that demonstrate increases in migration 'on the margin' (or on net) do not increase understandings of 'who' migrates and 'why' they migrate. Targeting policy at those who are most prone to migrate and understanding the causes that must be addressed are what policymakers need.

Multiple contextual conditions shape migration decisions. Local conditions that can lead to migration include threats to human wellbeing such as violence, disease, lack of economic opportunities, and food insecurity. The capability of the individual migrant and their family to pursue migration is important (Carling and Schewel, 2018; Kaczan and Orgill-Meyer, 2020; van der Land, 2017)—migration has been shown to be positively related to: household wealth, household size (cover loss of migrant's labor), and to the level of social networks along migration routes and at destinations (De Janvry and Sadoulet, 2000; Latapí et al., 1998; Mines and de Janvry, 1982; Romankiewicz and Doevenspeck, 2015). Research has shown that given differences in cost, risks, and benefits, decisions surrounding seasonal and more permanent (≥1 year) migration are qualitatively different and affected by different factors (Jones and Garst, 1981; Kaczan and Orgill-Meyer, 2020; Panda and Mishra, 2018; van der Land, 2017).[1] Research has

1 In both source regions, there is a long history of seasonal emigration built into rural livelihood strategies with recurrent moves among places where migrants maintain enduring ties (King, 2013). Seasonal labor migration is less costly and disruptive to rural productive activities and is supported by social networks to facilitate movements and hosting at destinations. Decisions to emigrate beyond a year, which include those with destinations in the United States or Europe, are qualitatively different. These decisions are often made at the time of departure and are known by other family members. They have higher costs (labor lost and financial investment), greater risks, and potentially a higher rewards. Decisions to emigrate for longer periods of time are less likely to be in response to a single crop loss but more likely result from longer-term subsistence struggles.

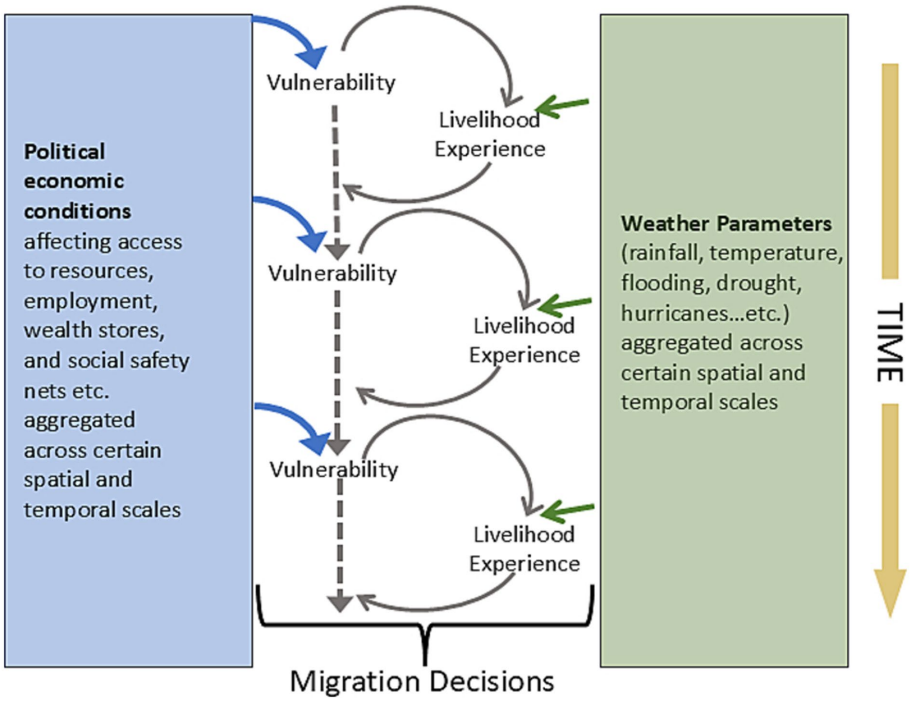

FIGURE 1
Vulnerabilities are contextual, constructed over time, and lead to the context in which migration decisions are made. Livelihood experiences are directly shaped by both existing vulnerabilities as shaped by political economic conditions and by the interaction of these vulnerabilities with weather parameters. Vulnerability is historically embedded, meaning that it is affected by prior vulnerabilities constructed over time. In line with existing work (e.g., Blaikie et al., 2004; O'Brien et al., 2007; Ribot, 1995; Ribot, 2023; Watts, 1983; Watts and Bohle, 1993), vulnerability precedes climate exposure. The blue and green arrows represent the impacts of material conditions (both political economic and weather related, across certain spatial and temporal scales) on prior vulnerabilities and livelihood experience. The gray loops and dotted lines represent, respectively, the compounding effects of prior livelihood experiences and vulnerabilities on the context in which migration decisions are made.

shown that migration decisions are made not solely by migrants themselves but in close coordination with other household members or in strong consideration of household needs (Cattaneo and Massetti, 2015; Dillon et al., 2011). These contextual factors, which shape migration decisions, need to be considered in any comprehensive analysis of climate-induced migration.

Climate change unfolds over many decades. Except in cases of catastrophic and violent weather events—major floods, droughts, or hurricanes—only changes in climate parameters over a number of years will likely result in decisions to move over greater distances for longer durations in what can be costly and dangerous journeys (Abrego and Menjívar, 2022; Grolle, 2015; Vogt, 2018). Moreover, people are not likely to leave because of climate parameters themselves (e.g., heat or drought) but rather because of the effects of these on food security, human health, and the social relations—aspects of human experience that are also affected by the social unit's (e.g., household, community) history of subsistence struggle and by the changing nature of the broader economic and policy environment (Figure 1).

Not everyone migrates under stress; those who leave due to climate change are the vulnerable, or people with limited ability to maintain their consumption levels or avoid losses and damages under changed climatic circumstances. Vulnerability is a condition preceding a climate hazard (Blaikie et al., 2004; O'Brien et al., 2007; Shukla et al., 2019). This insight derives from early research demonstrating that food insecurity cannot simply be explained by crop failures and food shortages but that the damage of climate hazards on peoples' prospects is shaped by their livelihoods, access to resources, relations with others, and positions with respect to markets for food, labor, and other commodities (Castro, 1952; Sen, 1981; Watts and Bohle, 1993). The causal nexus underlying climate-influenced migration involves multiple factors—some related to climate change and others not—working at a range of spatiotemporal and social organizational scales.

3 Method and causal inference

Given its complexity, studies of climate-induced migration risk well-known causal inference problems. These analytical problems can lead to false acceptance or rejection of hypotheses in both qualitative and quantitative research. They can stem from methodological design features that may be related to how the relationship of climate change and migration is conceptualized. While climate-induced migration is particularly complex, it is not unique, and it shares some common challenges with other climate-to-society questions:

1. Migration decisions, as discussed above, are likely to be affected by multiple factors. Studies that consider the effects of a wider range of predictor variables on migration decisions (including climate parameters) will be less likely to fall into the 'climate reductionism' trap (Dewan, 2023; Garip and Reed, 2025; Hulme, 2011, 2023). Ignoring the effects of non-weather

TABLE 1 Search terms in English, Spanish and French.

Language	Search terms			
	Migration	Climate	MesoAmerica	West Africa
English	migration, emigration, exodus, refugees, displacement, relocation, environmental refugee, environmental migration, Mexico border crossing	climate, rainfall, drought, hurricane, flooding, crop failures, hazard, impact	Central America, Honduras, Belize, Costa Rica, El Salvador, Guatemala, Nicaragua, Panama, Mexico	West Africa, Sahel, Mauritania, Senegal, Mali, Burkina Faso, Niger, Chad, Nigeria, Benin, Gambia
French	migration, émigration, exode, réfugiés, déplacement, migrant environnemental, migration environnementale, réfugié environnemental	climat, précipitation, sécheresse, ouragan, inondation, mauvaises récoltes, danger, risque, impact		Afrique de l'Ouest, Sahel, Mauritanie, Sénégal, Mali, Burkina Faso, Niger, Tchad, Nigeria, Benin, Gambie
Spanish	migración, emigración, éxodo, refugiados, desplazamiento, reubicación, refugiado ambiental, migración ambiental, frontera de México	clima, lluvia, sequía, huracán, inundación, Pérdida de cosecha, peligro	Centroamérica, Honduras, Belice, Costa Rica, El Salvador, Guatemala, Nicaragua, Panamá, México	

variables can lead to the spurious identification of outcomes as climate effects.

2. Climate parameters cause migration only through intermediate changes (harvest reductions, food shortage, work availability, intra-familial conflict, infrastructural damage, etc.) and thus measuring these intermediate changes strengthen causal claims about climate influence (Tuholske et al., 2024).[2] A further consideration is that these intermediary variables are affected not only by weather variables but by other factors—markets, social security arrangements, policies, land tenure, prior emigration, etc. Taking account of these other independent factors is important to making robust causal claims.
3. Understanding migration decisions requires analyses that are tied to the social unit and time frame in which such decisions are made. Inferring causal relationships at the individual and household level from statistical relationships found among aggregate parameters at broader socio-spatial scales are prone to what is known as the 'ecological fallacy' (Eklund et al., 2016; Helbling et al., 2021; Piantadosi et al., 1988). This causal inference problem stems from inferring causes of individual behavior from relationships between grouped data at aggregated (labeled as 'ecological') levels, such as the community, subnational district, or nation, and may not relate at all with the actual causes of individual or household decisions.

These represent major challenges facing research on the relationship between climate change and social phenomena. In this review, we focus on the methodological characteristics that are important for making defendable causal claims and how these characteristics are shaped by conceptual framing, data sources, and regional specificities.

4 Methods

4.1 Searches and coding

For both study regions, we conducted a set of searches for research published between 2000 and 2023. Table 1 presents the search criteria that were used in Google Scholar and Web of Science searches for English, Spanish and French language materials. We retained the first 2,400 publications from Mesoamerica and 1,800 from West Africa matching the search criteria.[3] Reviews of the titles and abstracts of these publications identified approximately 100 publications from each study region that report on empirical effects of climate parameters on human migration.[4] A closer reading of these publications winnowed down the sample to 53 Mesoamerican and 49 West African publications (see Appendix A).[5] These include peer reviewed articles, book chapters, dissertations, and gray literature such as policy reports and working papers.

2 Some may argue that since weather parameters are exogenous, it is preferable to solely use them as predictors in statistical analysis investigating climate-induced migration. The problem with this is that weather parameters are strongly mediated in migration decisions through their effects on different aspects of livelihood experience which are also affected by other factors. In this way, a weather parameter's effect on emigration is endogenous.

3 The lower yields from West Africa reflect the poor coverage in the Web of Science of French-language publications.

4 We removed publications lacking empirical analysis linking climate change and migration within the study regions. These include publications generally referring to the phenomenon without sufficient empirical information about climate or migration (or both), or those referring to the implications of the phenomena—such as discursive and legal analyses and implications for international relations. Review articles that did not present original empirical analysis using climate and migration data were also excluded.

5 In addition to cases outlined in the previous footnote that were less obvious in our initial review, some publications were not retained when the same analysis by the same author(s) was reported in multiple publications. For these, only one representative publication was retained in our review.

TABLE 2 Coding variables used to characterize published studies on climate-induced migration in West Africa and Mesoamerica.

Variable	Description
General characteristics	
PeerRev	The publication is a peer-reviewed publication or dissertation (0, 1)
Region	The source region of concern (Mesoamerica = 0, West Africa = 1)
ExtremeEvent	The climate change of concern is an extreme event (hurricane, extreme flooding etc.) (0, 1)
PrimaryData	The study involved primary data collection about migration decisions -interviews or surveys (0, 1)
Conceptual framing characteristics	
MigD_Other	Migration decision is recognized as being independently influenced by factors other than climate (0, 1)
MigD_Cap	The effect of the capability of individuals and households to migrate on migration decisions is considered (0, 1) reflecting their wealth, family size, social networks etc.
MigD_Hsld	Migration decision is not solely made based on an individual's situation and interests but also by those of the individual's household (0, 1)
Vuln_Context	Ordinal ranking of the degree of contextualization of vulnerability—vulnerability seen as simply shaped by CC exposure (0), exposure plus demographics (1), exposure interacting with livelihoods (2), exposure interacting with complex social dynamics and structures (3)
Vuln_CCMed	Ordinal ranking of how climate changes to impacts are mediated: no mediation, only CC (0), CC affects incomes (1), CC affects market dynamics or entitlements (2), CC change leads to complex social dynamics (3)
Vuln_Prod	Ordinal ranking of whether climate vulnerability is conceptualized as being produced over time: no consideration (0), passing reference (1), strongly incorporated into framing (2)
Spatiotemporal scaling of analysis	
SourceReg	Ordinal ranks of sociospatial scale of source region (community = 0, municipality = 1, district (region, province) = 2, nation = 3, multinational region = 4)
ScaleMig	Ordinal ranks of the sociospatial unit of aggregation of migration data for analysis (individual = 0, household = 1, community = 2, municipality = 3, subnational district (region, province) = 4, nation = 5)
ScaleClim	Ordinal ranks of the sociospatial scale of aggregation of climate data for analysis (household = 0, community/municipality = 1, subnational district (region, province) = 2, nation = 3, multinational region = 4)
TempMig	Ordinal ranks of the temporal extent of migration information used in analysis [0 (≤1 yr), 1 (1–5 yrs), 3 (6–10 yrs), 4 (11–20 yrs), 5 (>20 years)]
TempClim	Ordinal ranks of the temporal extent of climate information used in analysis [0 (≤1 yr), 1 (1–5 yrs), 3 (6–10 yrs), 4 (11–20 yrs), 5 (>20 years)]
Characteristics of methods (all binary)	
Meth_Qual	Overall qualitative methodological approach (0, 1)
Meth_Quant	Overall quantitative methodological approach (0, 1)
Method_Mix	Overall mixed methodological approach (0, 1)
MigDest	Migration destinations (international and domestic) distinguished in analysis (0, 1)
MigDur	Migration duration (seasonal vs. more permanent) distinguished in the analysis (0, 1)
ClimData	Climate data incorporated into analysis (0, 1)
SS_Match	Sociospatial scales of climate and migration data used in the analysis match (0, 1)
BiophysVar	Other biophysical data in addition to climate data are incorporated in analysis (0, 1)
AskWhyMig	Migrants or members of households are directly asked why they migrate (0, 1)
Exp_Cause	Explanations for uneven exposures to climate changes sought (0, 1)
MedSV	Social variables mediating the effect of climate incorporated in the analysis (0, 1)
IndSocVar	The effect of social variables on migration decisions independent of climate incorporated into analysis (0, 1)
CCB4Mig	Climate data used in the analysis precedes migration data (0, 1)

Beyond general research methods, we coded publications based on the criteria outlined in Table 2. Each study was coded for its general characteristics (type of publication, region, climate drivers, data source, migration source areas, destinations, and duration), Each study's conceptual framework was described through the coding of different characteristics of its conceptualization of migration decision-making and

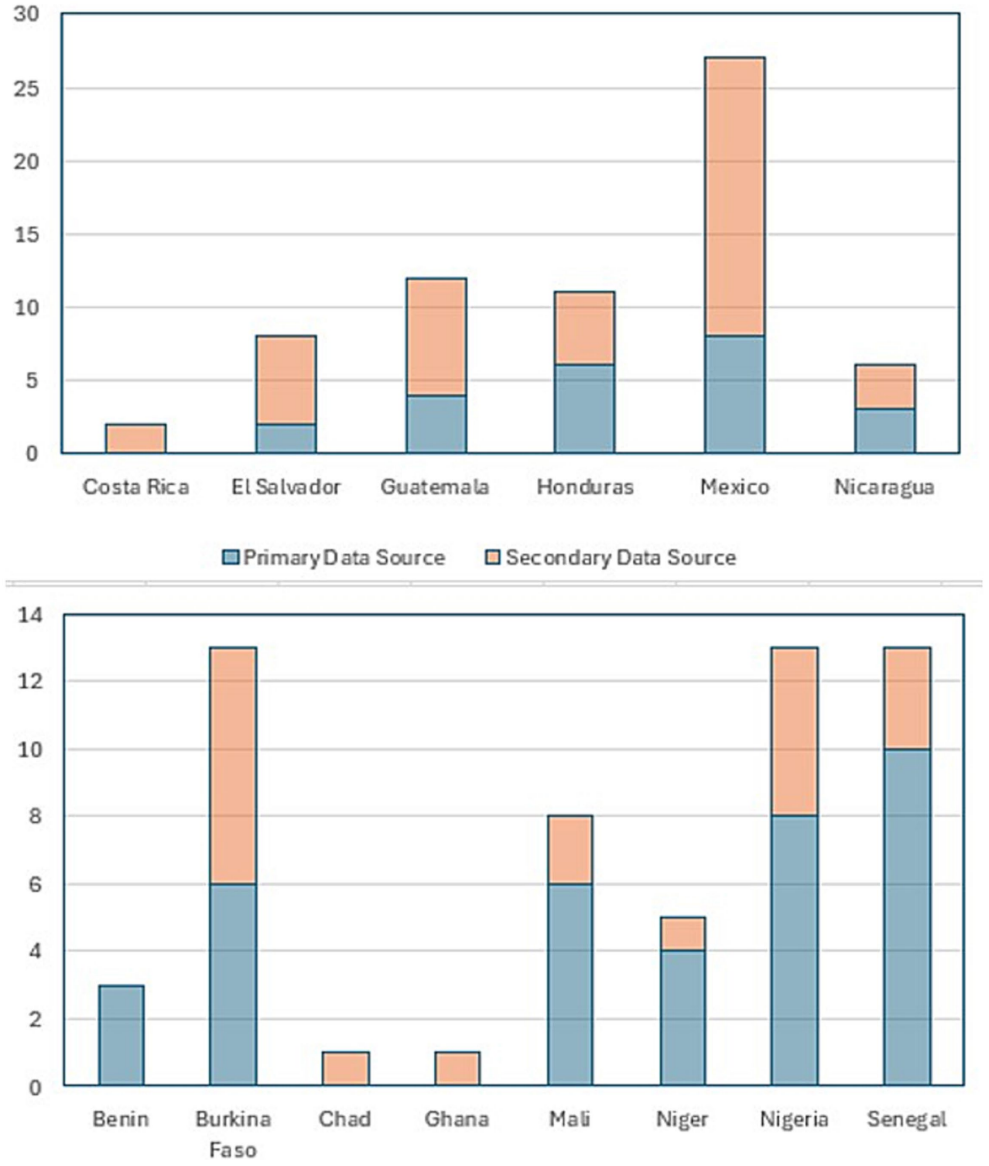

FIGURE 2
The geographical distribution of reviewed studies by country with those relying on primary and secondary data distinguished. These counts include multi-country studies across four or less countries. Studies that include more than four countries are excluded.

climate-related vulnerability. Coding of methodological characteristics was also performed including the socio-spatial and temporal scaling of analysis, overall methodological approach, the incorporation of climate, biophysical and social data, and spatiotemporal scale matching. In our coding, we endeavored to maintain a clear separation between the coding of conceptual framing and methodological characteristics. Conceptual framing relates to how migration decisions and climate vulnerability were described and characterized in the introduction and literature review sections. In addition, such framings were revealed by how researchers interpret their results and place them in relationship with other work within discussion sections. In contrast, methodological coding was based largely on a careful reading of the methods sections of publications. In some cases, when methods are poorly described, clarifications on data sources and analysis were sought in the results section or an appendix; this was the case with a small minority of the 102 publications reviewed.

Coding was a group effort but with the second and third authors taking the lead—each focused on a particular regional literature. To ensure that coding was performed consistently, coders conducted an initial review together and frequently discussed their subsequent coding with each other and with the first author. We went through several iterative rounds of coding, as more nuanced coding protocols for certain parameters were developed throughout the process. In cases where coding proved difficult, more than one author reviewed the paper to determine the appropriate code. It should be noted that the methodological codes included not only those simply documenting the socio-spatial and temporal scaling (SourceReg, ScaleMig, ScaleClim, TempMig) or overall methodological approach (Meth_Qual, Meth_Quant, Meth_Mix), but others that reduce the potential for the causal inference problems of climate-to-migration analyses described above (MigDest, MigDur, SS_Match, ClimData, BiophysVar, AskWhyMig, Exp_Cause, MedSV, IndSocVar, CCB4Mig).

Reviewed papers range from highly quantitative to deeply qualitative. Every effort was made to treat studies consistently despite large differences in general methodology. This was particularly the case for coding related to the incorporation of social and biophysical variables into the analysis (e.g., MedSV, IndSocVar, ClimData, BiophysVar). Variables that were presented but not brought into an analytical model relating climate parameters to migration (statistically or qualitatively), either as mediating or independent factors, were not coded as having been incorporated into the analysis. This was an issue for some qualitative studies that simply present climate information alongside migration information with limited analytical attention to their relationship. The incorporation of social variables as mediating climate impacts (MedSV) or acting independently from climate impacts (IndSocVar) were sometimes difficult to distinguish in large statistical models with many variables. Significant effort was made to distinguish variables that were used as demographic controls or to measure the capacity to migrate from variables that were incorporated as mediating climate effects or as independent factors directly contributing to migration decisions.[6]

4.2 Analysis

Our analysis proceeded in two steps: 1. Studies were grouped based on the six conceptual framing codes using cluster analysis; and 2. Regression analysis evaluated how these conceptual groupings, data sources, climate change type, and region are related to methodological characteristics of studies. In this way we use statistical techniques to identify groups of studies that share a common conceptual framing and then determine whether these, along with data source, region, and climate change type, affect the methodological characteristics outlined in Table 2.

First, to identify major conceptual framings in the literature, we used the six conceptual framing codes outlined in Table 2. These characteristics are measures of the degree to which the conceptualizations that underlie studies derive from prior social scientific work and thus incorporate more nuanced contextual understandings of: 1. migration decisions, measured by three binary variables (MigD_Other, MigD_Cap, MigD_Hsld); and 2. climate change vulnerability, measured by three ordinal variables (Vuln_Context, Vuln_Prod, Vul_CCMed). A hierarchical cluster analysis on the normalized values of these six characteristics was performed using Ward's linkage and Gower's dissimilarity. Determination of the number of clusters to retain (3–5) for subsequent analysis was determined by an inspection of cluster dendrogram and the trend in the values of Calinski/Harabasz Pseudo-F as the number of clusters increased.

Second, we assessed how methods used in studies reflect their conceptual framing as measured by the study's membership in clusters. Methods used in studies could be influenced by not only the conceptual framing of the study but also the type of climate change being considered (processual versus extreme event), the data (primary versus secondary data), and the region of study and associated research traditions (West Africa versus Mesoamerica). The relationship between these independent variables (conceptualization, climate change, data, region) and the sociospatial and temporal scaling of the study design was analyzed through ordinal regression analysis of each scaling variable. Likewise, each binary variable defining a key methodological characteristic of each study (see Table 2) was assessed using logistic regression with the same set of independent variables.

5 Results

Of 102 publications reviewed, 89 were peer-reviewed (articles or book chapters) or academic theses, and 13 were 'gray' literature. The climate changes of concern were dominated by longer-term progressive changes in temperature and/or rainfall (79%) with a smaller fraction focused solely on extreme events (11%) or both long-term changes and extreme events (11%).

Among the Mesoamerican studies, a high number focused on Mexico; in West Africa, more focused on Burkina Faso (Figure 2). The larger number of studies focused on Mexico and Burkina Faso reflect the higher public availability of longitudinal climate and migration data in each country.[7]

5.1 Dominant patterns in conceptual framing

Cluster analysis of the reviewed studies based on six conceptual framing characteristics identified three distinct clusters (with high dissimilarity between and low dissimilarity within clusters).[8] Table 3

6 If social variables not measuring the capacity of individuals or households to migrate were included in statistical models, these were seen as part of the analysis even if they were used as controls (no effect presented or discussed). Distinguishing between a study's use of a social variable as a mediating (MedSV) or independent variable (IndSocVar) can be difficult. In such cases, our coding reflects how the researchers' discussed these variables. For example, a measure of violence would be treated as affecting migration independently of climate change unless the authors explicitly discuss the possibility of climate change leading to violence. If so, the violence measure would be seen as a mediating social variable (MedSV = 1) and not as an independent social variable (IndSocVar = 0).

7 Numerous studies in our sample draw on migration data from Mexico's National Institute of Statistics and Geography (INEGI) Censuses including the Mexican Migration Project (carried out since 1982), and the EMIF Border Surveys (*Encuesta Sobre Migración en la Frontera Norte*, carried out since 1993 and *Encuesta Sobre Migración en la Frontera Sur*, carried out since 2004). The Burkina Faso studies relied on data from a national household-level survey on migration conducted by the *Unité d'Enseignement et de Recherche en Démographie* (UERD). Papers published after 2009 also utilized data from a follow-up survey conducted by the African Monsoon Multidisciplinary Analysis (AMMA) project, which collected information (in 2007–2008) about perceptions of climate change and experiences with migration over the previous 20 years in five West African countries.

8 There was no significant break in the measure of the cluster distinction (Calinski/Harabasz Pseudo-F) since the major distinction occurred with the first split—group 1 versus groups 2 and 3 with a Gower Dissimilarity Measure (GSM) of 15. Groups 2 and 3 were the next split with a lower GSM of 7. Groups 1 and 2 were subsequently split at a similar GSM (3) with the differences between the resulting pairs caused by a single variable. For this reason, three clusters were retained for subsequent analysis.

TABLE 3 Study clusters defined by the conceptual framing of the contexts in which migration decisions are made and climate vulnerability produced.

Cluster	#	Means of variables used in cluster analysis					
		MigD_ Other	MigD_Cap	MigD_Hsld	Vuln_Context	VulnCCMed	Vuln_Prod
1	45	0.18	0.27	0.00	0.96	0.62	0.27
2	24	0.17	0.67	1.00	2.00	1.17	0.67
3	33	0.88	0.91	0.61	2.85	2.73	1.52
Total	102	0.40	0.57	0.43	1.81	1.43	0.76

The means of the migration decision (MigD_Other, MigD_Cap, MigD_Hsld) and vulnerability framings (Vuln_Context, VulnCCMed, Vuln_Prod) used to define clusters are presented as well as the number of studies (#) within each cluster.

presents the means of the conceptual characteristics for each cluster. A significant finding is that these contextual measures, each representing different dimensions of more nuanced understandings of migration decisions or climate vulnerability, vary together across the three clusters.

Cluster 1, the largest cluster, holds 45 publications framed in a manner largely decontextualized from (a) how migration decisions are made and (b) the nature of climate vulnerability. These studies have the lowest mean values for all six conceptual framing variables (Table 2). We refer to studies in this cluster as decontextual since they tend to ignore or deemphasize: 1. Factors, besides climate, that influence migration decisions, and; 2. How and why certain individuals and households are vulnerable in the face of changing or existing climate stresses. Many of these studies assume a direct linear-causal relationship between climate and migration, with exposure of people directly causing emigration with little attention to mediating factors or how decisions are made (e.g., Naugle et al., 2019; Sivisaca et al., 2021; Spencer and Urquhart, 2018; Uzoma et al., 2018). Vulnerability, if considered, is seen as a static state rather than developing over time as a process with its own causes that must be considered as contributing to the production of damages or outcomes such as migration (e.g., Bermeo and Leblang, 2021; Ferris and Stark, 2012; Olivera et al., 2021). Some studies in this cluster use income shocks or declines in agricultural yields as mediators of climate impact, but do not analyze livelihood arrangements, resource access, or historical processes leading to current market conditions (e.g., Feng et al., 2010; Fishman and Li, 2022; Linke et al., 2023; Olaniyan and Okeke-Uzodike, 2015; Pearson and Niaufre, 2013). Several West African studies in this cluster also tied population growth to migration through outdated ideas of carrying capacity (Forsyth, 2002; Sayre, 2008), without consideration of any contextual aspects that might mediate the relationships between people and their resource base (e.g., Fricke, 2004; Hamro-Drotz, 2014; Naugle et al., 2019; Uzoma et al., 2018).

In contrast, the conceptual framings of Cluster 3 studies ($n = 33$) (we return to Cluster 2 below) show high engagement with the complexity of migration decisions and climate-related vulnerabilities. Five out of six means of the conceptual variables are higher than those for clusters 1 and 2 (Table 3). These studies generally conceptualize climate-related vulnerability in a more nuanced fashion, consistent with the social science literature as depicted in Figure 1. Migration decisions are shown to involve others (e.g., members of migrants' households) and are shaped by many factors beyond climate and by the capacity of prospective migrants to migrate. Generally, studies in this cluster conceptualize migration decisions made by the most climate vulnerable as shaped over time, not only by characteristics of individuals, households, and communities, but also by broader structural-institutional factors (e.g., political climate, inequality, marginalization).

Cluster 3 studies often attend to the household and community contexts in which migration decisions are made, as in Schmidt's (2019) consideration of migration histories, farmer age, and culture in Mexico. Examples in Cluster 3 include qualitative and mixed-methods work that is attentive to the processes that lead to shifts in the unequal control of land and labor among different rural groups (see Radel et al., 2018; Rivaud Delgado, 2017; Romankiewicz et al., 2016; Wrathall et al., 2014) such as rural women (see Ayales et al., 2019; Nagabhatla et al., 2021; Radel et al., 2016; Thiam and Crowley, 2014). Quantitative studies within this cluster, while not explicitly referring to vulnerability, distinguish the effects of climate parameters among different social groups due to differences in resource endowments and livelihood practices (e.g., De Longueville et al., 2019; Juarez Sanchez et al., 2022; Makanju and Uriri, 2022).

Cluster 2 (24 publications) falls in between the extremes of Clusters 1 and 3 with intermediate values for five of the six characteristics (Table 3). All members of Cluster 2 consider how migration decisions are made by individuals in interaction with their families (e.g., Dupre et al., 2022; Marín, 2021; Zickgraf, 2022). We find variation across studies in Cluster 2 in terms of whether they use a socially mediated framework. A subset of these studies treats climate parameters as directly causing migration without a consideration of intervening social variables (see Afifi, 2011; Nawrotzki et al., 2015). Others attend to how changing livelihoods as well as other social factors mediate migration at a household level including the effects of coffee leaf rust in Guatemala (Dupre et al., 2022); and seasonal migration's sensitivity to food vulnerability in Niger (Bello, 2019). Some studies show significant attention to migration capability such as Cattaneo and Massetti's (2015) consideration of access to credit and market opportunities in Nigeria. Still, other studies consider capability to migrate by focusing on social networks but omit deeper analyses of social relations (e.g., Hunter et al., 2013; Nawrotzki et al., 2015).

In sum, studies cluster in three distinct groups that differ consistently across all six contextual variables. For the purposes of subsequent discussion, Cluster 1 studies will be referred to as decontextual studies while Cluster 2 as contextual light studies, and Cluster 3 as contextual studies.

5.2 Socio-spatial and temporal scaling of studies

Major sources of variation across the reviewed studies are the socio-spatial and temporal scales of analysis. Emigration source areas varied from a single community to multi-national regions (SourceReg). The sociospatial scales of the unit of migration (ScaleMig) and climate variables (ScaleClim) used in analyses also varied widely. Aggregation is common in order to match the scales of climate and social data in analysis. Climate point data necessarily are used to describe rainfall and temperatures over broader areas. In regions where ground-level climate data are sparse, these areas can be quite broad and migration and other social data may be aggregated to provincial or even national levels to better match climate data. Such aggregation has risks, since inferring individual or household migration decisions from aggregated migration data (counts or means) is risky due to the 'ecological fallacy' grouping problem (Piantadosi et al., 1988). As shown by a number of studies (Abel and Cohen, 2019; Kirchberger, 2021), migration data as well can have gaps and problems of aggregation that can lead to sociospatial scaling issues in analyses. In addition, both climate and migration data may only be available for circumscribed time periods. As a result, we find that reviewed studies varied in terms of the temporal extent of both migration (TempMig) and climate information (TempClim) used in analyses, whether qualitative or quantitative. We would expect studies of climate change impacts to trace decadal shifts in weather parameters, but this was not always the case.

We looked at the relationship of socio-spatial and temporal scale of analyses to four different independent factors: the nature of climate change being modeled (ExtremeEvent), the region of focus (Region), the collection of primary data (PrimaryData), and the conceptual framing of the study as measured by membership in the contextual and contextual light clusters.[9] Table 4 presents the results of the ordinal logistic regression analyses of five scaling variables on each of these independent variables. The odds ratio is presented to provide a sense of the magnitude of the influence of independent variables on the likelihood of scaling characteristics of the reviewed studies. For those relationships that are statistically significant, the odds ratio (OR) is equal to the changed odds of the dependent ordinal variable changing its value if the binary independent variable is present (1).[10]

Those studies involving the collection of primary data (PrimaryData) on migration through interviews and surveys are understandably associated with narrower socio-spatial scaling (more local) with primary data collection increasing the odds of reducing scale with ORs of 0.08, 0.25, and 0.06 for SourceReg, ScaleMig, and ScaleClim, respectively. West African studies generally had narrower scaling (0.24 OR) of migration data (ScaleMig) but broader scales (3.78 OR) for climate data aggregation (ScaleClim). This finding may be associated with the lower availability of climate data at finer scales as well as reduced availability of census-level migration data, increasing the potential for scalar mismatches. More contextual studies tend to have narrower socio-spatial scaling of migration data used in analysis (particularly contextual light studies). In sum, those studies that collect primary data and that have more contextual framing tend to analyze more narrowly framed migration data and therefore are less prone to causal inference problems tied to the ecological fallacy.

Temporal scaling is significantly shaped by the climate change of focus with studies of the effect of extreme events on migration tending to have shorter temporal extents of both climate (0.19 OR) and migration (0.33 OR) information. This was common among the Mesoamerican subset focusing on the impacts of hurricanes, such as 1998 Hurricane Mitch (e.g., Carvajal and Pereira, 2010; Griffith, 2020; Loebach, 2016). While contextual studies have a weak positive relationship to the temporal breadth of migration information used, contextual light studies have a stronger opposite relationship with these studies tending to have a shorter temporal extent. It is important to note that we could only confidently discern the temporal extent of the data used for a subset of studies (82 for TempCLim and 78 for TempMig). This reduced sample size possibly introduced some bias via study exclusion and may have influenced these findings.

5.3 Methodological characteristics of studies

The general methodological approaches used by reviewed studies are dominated by quantitative approaches (Meth_Quant) (48%) followed by qualitative (Meth_Qual) (30%) and mixed (Method_Mix) (22%) approaches (Table 5). Methodological characteristics that arguably improve causal inference also vary across the reviewed studies—from 19 to 80%. As with the socio-spatial and temporal scaling, we are interested in how climate change type (ExtremeEvent), region (Region), type of data used (PrimaryData) and the conceptual

9 Frequency analyses were performed among independent factors and it was found that the chi-square statistic was significant for a positive association of PrimaryData and Region (Pearson Chi-Square = 7.7, p = 0.005) and for a negative association between ExtremeEvent and Region (Pearson Chi-Square = 6.2, p = 0.01). Still, it was determined that the degree of association was not too high to exclude Region from the analysis since the cases that deviate from the statistical association between these two sets of binary variables are equal to 41 and 36% of all cases for Region correspondence with PrimaryData and ExtremeEvent, respectively. Moreover, excluding Region as an independent factor from the ordered logistic regressions did not significantly influence the significance or sign of the coefficients of other independent factors.

10 When statistically significant, the odds ratio provides an estimate of the odds of moving to a higher category of the ordinal outcome variable when the binary variable is equal to 1. ORs give a sense of the magnitude of response from changes in the independent variable but can be misleading because they are tied to univariate logistic regressions and thus do not control for the effects of other independent variables. For odds ratios of less than 1, there is a negative relationship between the variables with the presence of the independent variable increasing the odds of a reduction in the value of the ordinal dependent variable.

TABLE 4 Factors affecting the sociospatial and temporal scaling of analyses of climate-induced migration.

Dependent spatiotemporal scales of analysis	Ordered logistic regression parameters				Extreme event driver (1 = yes)			Region (West Africa = 1)			Primary data collection (1 = yes)			Contextual light (cluster 2)			Contextual (cluster 3)		
	N	LR	p	R^2	OR	Z	p	OR	z	p	OR	z	p	OR	z	p	OR	z	p
SourceReg *Sociospatial scale of source region*	102	45.03	****	0.13	1.87	1.30		0.70	−0.87		0.08	−4.57	****	0.95	−0.11		0.65	−0.79	
ScaleMig *Sociospatial migration unit*	95	45.52	****	0.14	1.39	0.66		0.24	−3.22	****	0.25	−2.76	***	0.29	−2.19	**	0.56	−1.07	
ScaleClim *Sociospatial scale of climate data*	97	38.53	****	0.14	2.66	1.93	**	3.78	3.09	***	0.06	−4.89	****	0.55	−1.15		2.94	1.83	*
TempClim *Temporal extent of climate data*	82	14	**	0.06	0.19	−3.00	***	1.07	0.15		1.41	0.66		0.67	−0.72		1.68	0.93	
TempMig *Temporal extent of migration data*	78	16.74	***	0.07	0.33	−2.00	**	0.68	−0.82		0.81	−0.39		0.26	−2.15	**	2.66	1.66	*

The results of separate ordered logistic regressions with scales of analysis as dependent variables with climate change being an extreme event (ExtremeEvent), source region (Region), use of primary data (PrimaryData) and the conceptual framing of migration decisions and vulnerability (Clusters 2 and 3) as independent variables. The overall model parameters are presented number (*n*), Likelihood ratio Chi² (LR), significance value (*p*) and Pseudo R^2 (R^2), followed by odds ratios (OR), *z* values, and significance levels for each independent variable.
*<0.1,**<0.05,***<0.01,****0.001.

framing of the study (contextual and contextual light) affect analysts' choices of methods. Table 5 presents the results of logistic regressions of these independent variables on each methodological characteristic. Odds ratios (ORs) are presented that are estimates of how the independent variable (ExtremeEvent, Region, PrimaryData, Contextual Light, Contextual) changes the odds that a dependent methodological feature will also be present in the reviewed studies.[11]

The prevalence of qualitative, quantitative, and mixed method approaches is associated with the nature of data used (primary versus secondary) and the conceptual framings adopted by researchers. The prevalence of qualitative studies is not influenced by any of our independent variables. Quantitative methodological studies are less prevalent among studies relying on primary data collection (0.3 OR) and those that show a greater engagement with contextual realities of migration decisions and climate vulnerability as members of contextual framing Cluster 3 (0.2 OR). To conclude that a greater engagement with context results in a rejection of quantitative analysis would be wrong, however. Mixed methods, incorporating both qualitative and quantitative analyses, are positively associated with the contextual framing Cluster 3 (5.0 OR) as well as with primary data collection (5.3 OR).

Research has shown that decisions about migration differ based on whether migration is seasonal (versus semi-permanent stays exceeding a year) or domestic (versus international). Of the reviewed studies, 57% did not distinguish duration (MigDur) (e.g., Sanfo et al., 2017) while 20% did not distinguish destination (MigDest) (e.g., Camacho Zavala, 2015; De Longueville et al., 2015) in their analyses. While none of the independent variables are significantly related to whether analyses distinguish between domestic and international destinations, distinguishing between seasonal and other types of migration is associated with studies relying on primary data (5.7 OR), and conducted in West Africa (10.7 OR).[12] This reflects the greater attention in West Africa to dry-season migration which is more prevalent than in Mesoamerica, as well the greater political attention on semi-permanent or permanent migration from Mesoamerica to the United States.

In 29% of the studies, a scalar mismatch existed between migration and climate data (SS_Match = 0). This is despite the fact that we were conservative in how we coded, recognizing data limitations, with cases of climate data aggregated to community/municipal levels tied to individual and household migration data treated as scalar matches. Most commonly, mismatches occur with the incorporation of climate data at a broader spatial level, typically at a sub-national level (local or regional administrative districts), while migration data is analyzed at the

11 Only in cases where the relationship is significant can odds ratios be interpreted in this way and even in these cases, they can be misleading because they are estimated through univariate logistic regressions and thus do not control for the effects of other independent variables. ORs less than one are equal to the reduced odds of the outcome variable resulting from the independent variable being associated with studies. ORs greater than one are equal to the increased odds of the outcome variable due to the independent variable.

12 Reliance on secondary data is associated with a lack of distinction of migration duration—researchers are likely to be relying on census data where seasonal and semi-permanent departures are not always clearly distinguished.

TABLE 5 Factors affecting methods used in analyses of the climate-induced migration.

Method characteristic (0, 1)	%	Logistic regression parameters				Extreme event driver (1 = yes)			Region (1 = West Africa)			Primary data collection (1 = yes)			Contextual light (Cluster 2)			Contextual (Cluster 3)		
		C	LR	*p*	R^2	OR	*z*	*p*	OR	*z*	*p*	OR	*z*	*p*	OR	*z*	*p*	OR	*z*	*p*
Meth_Qual *Qualitative Approach*	30	0.20	7.02		0.06	2.14	1.38		1.12	0.23		2.61	1.66	*	1.01	0.02		1.04	0.06	
Meth_Quant *Quantitative Approach*	48	4.02	36.12	****	0.26	0.46	−1.21		1.19	0.31		0.15	−3.39	****	0.94	−0.10		0.23	−2.28	**
Method_Mix *Mixed Approach*	22	0.05	22.70	****	0.21	0.72	−0.45		0.79	−0.39		5.25	2.18	**	1.43	0.41		4.96	2.06	**
MigDest *Destination defined*	80	7.02	7.60		0.08	0.59	−0.86		1.56	0.77		0.34	−1.54		1.78	0.69		0.76	−0.40	
MigDur *Duration defined*	43	0.05	45.97	****	0.33	2.35	1.23		10.72	3.88	****	5.74	2.87	***	1.10	0.13		2.57	1.35	
ClimData *Climate data included*	65	3.98	15.96	***	0.12	0.42	−1.57		1.23	0.41		0.16	−2.91	***	2.46	1.29		1.54	0.66	
SS_Match *Sociospatial scale match*	71	3.19	15.36	***	0.12	1.23	0.32		0.31	−2.23	**	7.28	2.98	***	0.64	−0.66		0.19	−2.30	**
BiophysVar *Other biophys data included*	35	0.13	24.05	****	0.18	0.53	−0.95		5.64	3.29	****	2.01	1.71		0.78	−0.37		2.06	1.13	
AskWhyMig *Asked why migrate*	41	0.00	85.83	****	0.62	4.57	1.58		34.54	3.54	****	45.37	4.05	****	14.64	2.64	**	14.74	2.64	***
Exp_Cause *Explain uneven exposure*	19	0.01	25.81	****	0.26	3.56	1.68	*	1.14	0.21		1.17	0.21		9.37	1.81	*	38.91	3.04	***
MedSV *Includes mediating social variables*	69	0.81	31.32	****	0.25	0.53	−1.01		0.99	−0.02		1.90	1.02		2.77	1.65	*	27.37	2.98	***
IndSocVar *Includes independent social variables*	72	7.95	28.32	****	0.23	1.25	0.31		0.13	−3.31	****	0.35	−1.62		1.42	0.51		5.87	2.32	**
CCB4Mig *Climate precedes migration data*	54	0.52	25.03	****	0.18	0.33	−1.87	*	0.93	−0.15		1.00	−0.01		6.09	2.86	***	7.94	3.23	****

The results of separate logistic regressions with characteristics of methods (0, 1) dependent variables with climate change being an extreme event (ExtremeEvent), source region (Region), use of primary data (PrimaryData) and the conceptual framing of migration decisions and vulnerability (Clusters 2 and 3) as independent variables. The overall model parameters, Constant (C), Likelihood ratio Chi² (LR), significance value (*p*) and Pseudo R^2 (R^2) are presented followed by coefficients, *z* values, and significance levels for each independent variable.

*<0.1,**<0.05,***<0.01,****<0.001.

10.3389/fclim.2025.1549686

individual or household levels (e.g., Haeffner et al., 2018; Turner et al., 2023; van der Land, 2017).[13] A reliance on secondary data (SS_Match=0) increases the potential for scalar mismatches which reflects the constraints imposed by relying on the data of others whose sampling and collection protocols were likely not guided by climate-induced migration questions. In addition, scalar matches are less common in West Africa (0.31 OR), most likely due to the low availability of data, leading to use of climate data over broad areas and a greater reliance on primary migration data collection at the local level.

The incorporation of climate data, found in only 65% of the studies reviewed (ClimData), is negatively related to studies relying on primary migration data (0.16 OR). This reflects the greater ease of quantitative analyses using secondary data to incorporate climate data compared to qualitative analyses. Researchers relying on primary data collection, such as interviews, sometimes present climate data in a figure or table without integrating them into analysis. Others utilize perceptions or memories of climate change, rather than measures like temperature or rainfall, as their climate data, arguing that it is the perception that influences the migration decision (e.g., Akinbami, 2021; Ekoh et al., 2023; Juarez Sanchez et al., 2022; Rivaud Delgado, 2017). Others use perceptions in parallel with climate data, often at broader scales (e.g., Ayales et al., 2019; De Longueville et al., 2015; Estrada and Oswald, 2011; Griffith, 2020; Sanfo et al., 2017). The degree to which other biophysical variables that mediate climate effects (BiophysVar) are included in the analysis was found to only vary by region, with West African studies more likely to do so (5.6 OR) with the preponderance of these cases incorporating various measures of soil fertility and degradation. This reflects longstanding concerns about desertification and land degradation being a major constraint to agricultural productivity in the region (Benjaminsen and Hiernaux, 2019).

Climate changes are spatially heterogeneous, and environmental hazards stemming from them are variable even within a circumscribed area (Anderson et al., 2019; Turner, 2016). The impact of climate change is shaped by both uneven exposures and uneven vulnerabilities to the same exposures. Of all the methodological characteristics we coded for, studies that sought to explain uneven exposures (Exp_Cause) were the least prevalent (19%). Contextual conceptual framings are more likely to seek explanations for uneven exposure to climate hazards (OR 38.9).

Reviewed studies incorporate social variables into their analyses as either mediating climate effects (MedSV) (69%) or having independent effects (IndSocVar) (72%) on migration decisions. These are methodological features that are important to avoid spurious correlations that may arise from simply relating weather fluctuations with emigration rates. The conceptual frameworks brought to bear on the empirical data were found to strongly influence the evaluation of both independent and mediating social variables with studies within the contextual framing cluster positively associated with both (ORs 5.8 and 27.4 respectively). Examples of variables incorporated into analyses as mediating the effect of climate changes include land access (e.g., Dreier and Sow, 2015; Marín, 2021; Radel et al., 2018; Ramírez and Ramírez, 2016; Thiam and Crowley, 2014), access to credit (e.g., Hummel, 2016; Mounirou, 2022; Rivaud Delgado, 2017), declining coffee prices (e.g., Reichman, 2022; Ruiz-de-Oña et al., 2019), access to irrigation or other infrastructure such as roads (e.g., De Longueville et al., 2019; Haeffner et al., 2018; Nawrotzki and DeWaard, 2016; Nielsen and Reenberg, 2010), and small business ownership (e.g., Loebach, 2016). Social variables such as crime, violence (usually homicide rates), household wealth or macroeconomic context were commonly assessed as factors independently affecting the proclivity to migrate.

To understand the reasons people migrate, asking migrants and their families why they migrated, at the minimum, aids in the interpretation of the relationships among other variables (AskWhyMig). Surprisingly, only 41% of studies did so. Most of these studies involved primary data collection (OR 45.4) and used contextual conceptual framings (OR 14.6 and 14.7 for contextual light and contextual framings). These two relationships are understandable—analysts must engage with people to ask this straightforward but important question. What is less expected is that regionally, West African studies are more likely to directly ask this basic question to migrants and their families.[14]

A causal requirement of climate-induced migration is that for climate change to cause migration, it must precede migration (CCB4Mig). Surprisingly, in only 54% of the studies, the climate information preceded the migration data used in the analysis.[15] The other studies (46%) consider climate change as a trigger rapidly inducing people to migrate. Several studies that focused on the effects of progressive forms of climate change (e.g., temperature and rainfall) compare climate and migration data from the same set of years (e.g., Barrios et al., 2006; Bernabe Martínez, 2018; Britos et al., 2023; Castañer, 2017; Uzoma et al., 2018) or even have some of the migration data points precede climate data points (e.g., Aguirre and Tapia, 2020; Naugle et al., 2019; Neumann et al., 2015).[16] Having the same temporal range may make more sense for papers that look at extreme events,

13 Other studies had even larger spatial 'gaps' between their climate and migration data, measuring climate nationally or even multi-nationally while aggregating migration data to much smaller spatial scales (e.g., De Longueville et al., 2019; Ferris and Stark, 2012; Pearson and Niaufre, 2013; Uzoma et al., 2018). Some papers were considered a scalar mismatch since they did not specify the data's spatial scale, referring generally to increased storms, flooding, or drought at a regional or state/department level, for example, and/or presenting multiple or unspecified migration flows at various spatial scales (e.g., Casillas, 2020; Oswald Spring, 2020; Ruiz Meza, 2012; Sivisaca et al., 2015). Only a few studies incorporated climate data at a narrower scale than the scale of the incorporated migration data (Castañer, 2017; Gray and Wise, 2016).

14 This may reflect the lack of access to large-scale, reliable migration data in West Africa, requiring researchers interested in the climate-migration nexus to rely on their own migration surveys (and other primary data collection). Moreover, the one large migration data source used by 12% of reviewed studies in West Africa was the related datasets of UERD and AMMA that did include responses from migrants or their families about why they migrated.

15 Several studies, across methodological approaches, did not specify date ranges of the datasets for either climate data, migration data, or both (e.g., Anderson et al., 2010; Bleibaum, 2010; Casillas, 2020; Ba and Ngom, 2022; Ramírez and Ramírez, 2016; Sivisaca et al., 2015; Thiam and Crowley, 2014).

16 Some researchers attribute this practice to a lack of climate data or do not acknowledge such temporal sequences as problematic at all (e.g., Bello, 2019; Fricke, 2004; Makanju and Uriri, 2022; Mounirou, 2022; Neumann et al., 2015; Olaniyan and Okeke-Uzodike, 2015; van der Land, 2017).

such as hurricanes (e.g., Ferris and Stark, 2012; Saldaña-Zorrilla and Sandberg, 2009; Spencer and Urquhart, 2018), and in fact we found extreme events to be weakly and negatively associated with climate data used preceding migration data (OR 0.3). More rigorous studies recognize that changes in climate are often gradual and lead to a growing need among the most vulnerable to migrate over many years (e.g., Henry et al., 2004; Milan and Ruano, 2014; Radel et al., 2018). Studies adopting a more contextual conceptual framing were positively associated with the use of climate data that precedes migration outcomes (OR 6.1 and 7.9 for contextual light and contextual framings).

6 Discussion and conclusion

Our review reveals that while a large number of publications refer to climate-induced migration from Mesoamerica and West Africa, a very small fraction of these actually seek to empirically evaluate the causal connections between climate change and emigration. Scholarly research is not immune from popular narratives. The large number of references to climate-induced migration that lack empirical backing reflect both the dominant presumption in the popular press of a clear linkage between climate change and migration and the fact that confirming this presumption is empirically daunting.

6.1 Conceptual framing

Prior research has shown that migration decisions are not simply made by individuals in reaction to a single local condition such as a weather parameter—decisions reflect input from other household members with consideration of a suite of resources needed to migrate as well as local and extra-local factors that lead to decisions to emigrate from a particular area. Moreover, only those who are already vulnerable in the face of climate change can be seen to be compelled to leave by weather parameters (Blaikie et al., 2004). Our review finds that studies attentive to how migration decisions are made also tend to be attentive to the processes that make some more vulnerable in the face of climate stress. As a result, we were able to group studies based on the level of engagement for both how migration decisions are made and by whom (vulnerability). Studies that we call 'decontextual', the largest group of studies we reviewed, do not consider who is most vulnerable and how they make decisions to migrate. Our review has shown that decontextual studies, especially those that rely solely on secondary data, are most likely to have causal inference problems.

The treatment of vulnerability is a topic of sustained concern and engagement within the social dimensions of climate change literature (Blaikie et al., 2004; Pelling, 2003; Ribot, 1995; Temudo and Cabral, 2023). Social scientists and policymakers are interested in *who* is migrating and *why*, rather than whether climate change affects migration rates in the abstract. Policymakers must know the full range of sufficient and necessary causes in order to design effective and least costly risk reduction interventions. If the price of grains, for example, is what is making people's conditions so precarious that a small shift in the weather triggers hunger or instigates a decision to migrate, then the policy solution should focus on factors affecting grain prices. In our review, the decontextual group of studies implicitly equate vulnerability to damage, rather than viewing vulnerabilities as a set of pre-existing conditions that enable such damage. These studies thus implicitly or explicitly treat vulnerability as an outcome of climate exposure (O'Brien et al., 2007)—the unidentified group that migrates are vulnerable since migration is taken to be the 'damage' or outcome. Such analyses are unsatisfactory from a policy perspective—at best, confirming or not, the widely circulating narrative of the existence of 'climate-induced' migration, without any understanding of how pre-existing socio-ecological conditions may exacerbate or mitigate any climate effects, let alone inform policy.

Decontextual studies provide few insights on the vulnerabilities that predispose people to migrate when exposed to climate hazards. In narrowing the research question to whether or not there is a correlation between migration rates and weather fluctuations, they are also plagued with conceptual inference problems. People generally do not migrate because they are too hot, too dry, or too wet—instead they may migrate because heat, dryness, or flooding may lead to repeated crop failure or other social and economic hardships, and when confronting those hardships, over a number of years, they have no savings or social security arrangements to tide them over. These hardships are not determined by climate conditions but are shaped by other factors which may themselves be affected (or not) by climate parameters, among other causal factors, across a range of the spatiotemporal scales.

In the potentially high-risk/high-reward case of international migration, material conditions leading to emigration act over many years rather than simply in a single year. Over time, mediating socioeconomic factors are affected by other factors of shifting importance, some affected and many unaffected by climate change. Within such a causal nexus, it is easy to falsely reject a hypothesis of climate change impact given the high variation and complexity of migration causes. At the same time, the interpretation of an observed congruence (qualitative study) or statistically significant relationship (quantitative or mixed) is fraught without consideration of mediating factors that are actually felt by people as well as other factors that independently influence migration decisions. Within the web of factors influencing migration decisions within rural political economies, the chance of spurious correlations is high. Studies greatly benefit from incorporating mediating factors, independent factors, as well as information on how migration decisions are made, and by whom, to better understand who is vulnerable and what makes them vulnerable prior to a change in weather.

6.2 Data-driven analyses

The dominant narrative of climate-induced migration has also attracted researchers seeking to "test" the relationship where there are existing data sets. These data sets exist in regions of the world where there is a history of emigration. While not a focus of this paper, it is important to note that choosing regions where weather is variable and migration rates high, such as the focal regions of this review, can lead to significant bias toward finding a relationship.

Of the 102 reviewed empirical studies, 50% did not collect any primary data and instead sought to use existing data sets. Not surprisingly, 72% of these were studies adopting decontextual conceptual framings. A reliance on existing data sets has led studies to cluster around certain source areas with readily available census and climate information. This results in bias toward particular countries within our two source regions (Figure 2). The attractiveness of using

data from large-scale surveys or censuses is that it allows one to perform analyses over a much wider geographical area and presumably to generalize across particular contexts (decontextual studies). The appeal of using such data sets is misleading given that the data available are often not in the form, scale, or content to truly evaluate the relationship.

Migration data aggregation runs the risk of causal inference problems associated with inferring individual or household behavior from relationships found at larger aggregates such as subnational districts or nations ('ecological fallacy'). Studies relying solely on secondary data were also prone to adopt a number of methodological characteristics prone to additional causal inference problems (Table 5). No matter the sophistication of the analyses conducted, our review finds that allowing one's analysis to be shaped by the data at hand can be problematic unless one is attentive to the causal inference problems entailed by data choices.

6.3 Regional differences

The source regions of Mesoamerica and Sudano-Sahelian West Africa are both strongly implicated in popular, and arguably xenophobic, narratives of climate-induced migration (Piguet et al., 2018; Ribot et al., 2020). Still the two regions have different characteristics, data availability, and scholarly traditions that shape analyses of climate-migration relations. In West Africa, lower availability of climate and migration data to outside researchers has led to a number of methodological differences. Lack of fine-grained climate data has led to their wider aggregation for analysis. Less availability of widespread migration data (e.g., census) leads to more local collection of migration data. As a result of these scale trends, mismatches of the scale of climate and migration data are more common in the studies we reviewed on West Africa than in those on Mesoamerica.

Long-term concerns expressed within the popular and academic literatures also explain regional differences. In West Africa, there have been recurrent concerns expressed about desertification and land degradation (Benjaminsen and Hiernaux, 2019). The greater proclivity for studies in West Africa to include additional biophysical information in their analyses is most associated with the inclusion of land quality and soil information. Likewise, the greater inclusion of social variables that independently affect migration rates in Mesoamerica is explained largely by the inclusion of variables reflecting long-term marginalization, divestment from rural communities and political instability, such as literacy, poverty, and crime rates. In these ways, analyses were found to be affected by pre-existing regional concerns and assumptions.

6.4 Methods and causal inference

We find only weak relationships between conceptual framing and general methodological approach (quantitative, mixed, and qualitative). These findings call into question previous arguments such as by Cottier et al. (2022) that conflate conceptual framing with methodological approach and once conflated, treat contextual (qualitative) and decontextual (quantitative) approaches as simply different lenses on the question. Both are said to have value. Our review shows that neither such "even-handed" arguments nor general methodological reviews adequately address the causal inference questions at stake. Through the close reading of studies, we were able to identify more specific methodological characteristics that can contribute to causal inference problems and inhibit growth in understanding. Contextual framings, which were found to exist across the range of qualitative to quantitative approaches, are more consistent with prior social science work on migration decisions and climate vulnerability. Moreover, they are less prone to causal-inference problems. Relying solely on secondary data to enlarge sample sizes and increase statistical power does not address these problems but instead introduces additional ones.

The numerous causal inference problems that plague the study of climate-induced migration are not unique. Other areas of interdisciplinary scholarship linking climate change to social change are plagued with similar issues, most notably the climate-induced conflict literature (Adaawen et al., 2019; Benjaminsen, 2016, 2024; Brown et al., 2007; Burrows and Kinney, 2016; Hartmann, 2010). Our review shows that causal inference problems are not inherent to particular data sets or disciplinary backgrounds. They stem from the conceptual framing and methodological features chosen by researchers. Unless this is acknowledged, little progress in understanding the role of climate change and variability in migration decisions will be made.

To move forward, we urge researchers to take more seriously the inference problems that exist within the causal nexus of climate-induced migration. Studies that perform statistical tests of a climate effect on migration with existing large databases are built on the misguided assumption that all conditions affecting migration and mediating climate effects are controlled for across large sample sizes. Purely qualitative studies have different problems—the magnitudes of biophysical change and social response matter in the impetus for migration. But these are not the only options. As a number of innovative studies among those we have reviewed show—contextual framing and primary data collection are found across different methodological approaches. We agree with Romankiewicz and Doevenspeck (2015) that multi-scalar and mixed methods approaches show the most promise. Such approaches could use large secondary databases but combine them with primary data collection (quantitative and qualitative) within the same area to facilitate interpretation.

The causal inference problems illuminated in this review can be addressed through careful design of research that seeks to not simply identify the marginal effect of weather parameters on migration rates but instead seeks to identify who are most vulnerable, a preexisting condition to climate hazard exposure and confirm (or not) whether they are the ones that migrate after taking account of other factors contributing to migration. Migration is a deliberate act. It is remarkable that only 41% of the reviewed studies directly asked migrants or their families why they chose to migrate. To ignore the views of the people whose decisions are being modeled, about why they choose to migrate not only misses the opportunity to address potential causal inference problems but is problematic from an ethical perspective. The ease of statistical analysis of existing data sets is chosen over the 'difficulty' of speaking to people.

The policy relevance of existing climate-migration work is limited. As noted above, much of the reviewed work on climate-induced migration is focused on whether climate variability has a marginal effect on emigration rates. They provide little policy

guidance, which can only come by engaging more seriously with the questions of who migrates and why. The relationships found between climate parameters and migration rates by previous empirical studies are highly variable with no definitive relationship in either direction or magnitude (Borderon et al., 2019; Moore and Wesselbaum, 2022; Obokata et al., 2014; Šedová et al., 2021; White, 2011). This not only reflects a reliance on decontextual approaches across different contexts but the prevalence of causal inference problems identified by this paper. Both are failings of current research. Variable and contradictory research results open up space for unsubstantiated narratives that serve particular political and institutional prerogatives (Betts and Pilath, 2017; Durand-Delacre, 2023; Nicholson, 2014). As has been argued by Ribot et al. (2020), such narratives can work to naturalize the hopelessness that drives migration as simply an outcome of biophysical phenomena (climate change) rather than shaped by peopled histories and political economies at home. Within the context of widespread xenophobia, climate-induced migration is invoked to elicit concern about social dimensions of climate change in the Global South. Within this discursive space very little is said about the struggles or motives of migrants and any efforts to reduce their vulnerabilities in the face of a broader set of challenges including climate change. In these ways, policy needs to be informed by a better understanding of the climate change—migration nexus which will only come about if researchers truly grapple with the hard conceptual and methodological issues raised by this and other reviews.

Author contributions

MT: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. AR: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. EF: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. JR: Conceptualization, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This research was supported in part by internal awards at the University of Wisconsin-Madison to the first author including a Vilas Distinguished Achievement Professorship and funds provided by a Research Forward Initiative Grant awarded by the Office of the Vice Chancellor for Research and Graduate Education.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2025.1549686/full#supplementary-material

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