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Deciphering Impacts and Human Responses to a Changing Climate in East Africa

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Climate-related human mobility (climate mobilities) is often portrayed as a key impact of human-induced climate change. Yet, causal, quantitative evidence on this link remains limited and suffers from disciplinary hurdles. One reason for this is that existing case studies do not incorporate insights from climate science methods and pay little attention to contextual factors in climate mobilities. We use a dual-method approach to categorise and classify. By combining a qualitative case study analysis with statistical approaches from topic modelling in an innovative dual-method framework, we show current empirical evidence on weather and climate-related impacts and human mobility in East Africa, an alleged hot-spot of climate change. We find that although climate change is referred to, implicitly and explicitly, as a tipping point for human mobility, studies imply a causal link between human mobility and climate change while under or misrepresenting evidence in climate science. A map of evidence allows studies to be matched with human mobility types and contextual factors influencing such mobilities in a changing climate with a novel and more ambitious form of synthesis, carving out the multi-causal nature of human mobility. Our findings show that climatic influences on human mobility are not independent. Rather, climate factors influencing human mobility are closely connected with contextual factors such as social norms, economic opportunities, and conflict. The findings suggest that there is currently low confidence in a climate change-human mobility nexus for East Africa. As a way forward, we propose emerging methods to systematically research causal links between climate mobilities and anthropogenic climate change globally.

Keywords: extreme weather and climate, human mobility and migration, topic model analysis, case study analysis, compound extreme events

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INTRODUCTION

Throughout history, environmental and climatic changes have played a role in human mobility, but decisions to stay or move are multi-faceted; if any, climate and weather have been factors among many (Piguet, 2010; Black et al., 2011; Hoffmann et al., 2020). With growing concerns about the impacts of anthropogenic climate change, such factors are expected to grow in importance (Kelley et al., 2015; Lugli et al., 2019). Despite recent advancements, empirical evidence on the proportional impacts of a changing climate on human mobility is scant and currently thin on quantitative assessment (Abel et al., 2019; Cattaneo et al., 2019; Groth et al., 2020). Crucially, comprehensive evidence is missing for places vulnerable to a changing climate and potentially hot-spots of increasing hazards such as East Africa (Otto et al., 2020).

The Climate Change and Human Mobility Debate

Observed climatic change, independent of the cause of such change, human-induced climate change, and various forms of human mobility such as migration are discussed widely, and connect discussants from the public, policymakers, and academic researchers across disciplines (Gray and Mueller, 2012; Randall, 2015). Leading, in part, to a perceived causal chain between anthropogenic climate change, extreme events—often labelled as "climate change event," and associated mobility suggested in the migration literature portray an over-simplified picture of climate-related human mobility (Hastrup and Olwig, 2012; Hoffmann et al., 2020). Most of the debate, or at least a noisy part, has been framed by apocalyptic thinking or anti-immigrant sentiments (Haas, 2008; White et al., 2011), which construe particularly migration as a problem that needs to be solved. International organisations outline that migration will increase in so-called climate change hot-spots, or places where communities are already vulnerable to the physical and ecological effects of climate change (Rigaud et al., 2018). Despite their prevalence in climate migration rhetoric, such perceptions that problematise climate change-induced human mobility have been criticised for their insufficient scientific robustness, for example, in the context of conflict research (Abel et al., 2019; Ide et al., 2020). The migration-development literature provides a more nuanced understanding of human mobility (Klepp, 2017). Scholars in social science and development studies (e.g., Bakewell, 2008, 2010; Haas, 2008, 2010; Flahaux and De Haas, 2016) break down and clarify the often-misunderstood debate on migration and development: because human mobility requires financial capital, poverty reduces out-migration; and in turn, economic development and increased financial means lead to *more* migration (Bastia and Skeldon, 2020). With currently little consensus on appropriate research methods to identify whether and to what extent climate change affect human mobility, it is not clear what role human induced climate change plays in this nexus at present and in the future. Research that attempts to juxtapose the vast heterogeneity of topical perspectives have resulted in different concepts and terminologies (Piguet, 2010; Borderon et al., 2019; Hoffmann et al., 2020).

Review Approach and Contributions

This Review is guided by the question: How sound are the lines of evidence for a causal link between human-mobility and a changing climate in East Africa? Here, we provide a dual-method evidence approach, consisting of a qualitative case study analysis and a quantitative topic model that are set to disentangle the complex drivers of climate-related human mobility. Through the dual-method, we can reveal connexions between climate mobilities and contextual factors (e.g., food security and livelihoods) which a single-method approach would have otherwise masked.

To this aim, we systematically review the literature and explore the lines of evidence on the link between weather and climate-related events and human mobility (climate mobilities). We focus on the methodological compatibility (or lack thereof) from climate mobilities research stemming from different disciplinary spheres in a potential climate change hot-spot region (Byers et al., 2018). We show that climate data finds little application in existing climate mobilities literature in East Africa. This might lead to an oversimplified picture of human responses to weather and climate-related events. From the analysis, we can infer there is not yet a framework that allows for a disentangling of weather and climate-related human mobility drivers from non-climatic, contextual drivers, assessing the probability of climate change impacts, and outcomes. Our key takeaway is that the problematic use of climate and weather data is not limited to East Africa, but points to a wider problem in this field of climate change impact research which requires truly interdisciplinary research. Therefore, we outline the applicability of quantitative methods from econometrics and extreme event attribution to support the development of a more comprehensive understanding on human responses to weather and climate-related events and attributable links to climate change in future research. This analysis contributes to the ongoing effort of assessing the probability of climate change impacts and human responses to a warming climate.

METHODS

Study Area

East Africa (**Figure 1**) is vulnerable to climate change and variability and the impacts from extreme weather and compound events (Marthews et al., 2019). The region is characterised by a traditionally mobile population, consisting of pastoralists and herders. Human mobility is part of many livelihoods across East Africa (Collier et al., 2008; Shongwe et al., 2011; Uhe et al., 2018; Funk, 2020). In recent years, a number of extreme weather events have had significant social and economic impacts, including displacement, food insecurity and conflict. To illustrate, the 2015 drought in Ethiopia put an estimated 22 million people in need of food aid (Philip et al., 2017). In Somalia, 26 different flood, drought, and storm events have been recorded between 2010 and 2020 by the disaster database Em-DAT (Guha-Sapir et al., 2016).

Analytical Framework

The analytical framework consists of three elements: a systematic literature review, a resulting case study analysis and a topic model evaluation (**Figure 2**). While setting out to qualitatively analyse the case studies, we use a topic modelling approach to augment the understanding on the range and significance of contextual and climatic influences on human mobility in the study region. This dual-method approach allows us to synthesise and quantify the current evidence in the field.

Case Study Approach

In a broad and systematic search of the literature (see **Supplementary Section A** for a detailed description of the systemic literature review), we identified qualitative and quantitative studies that investigate the link between a variety

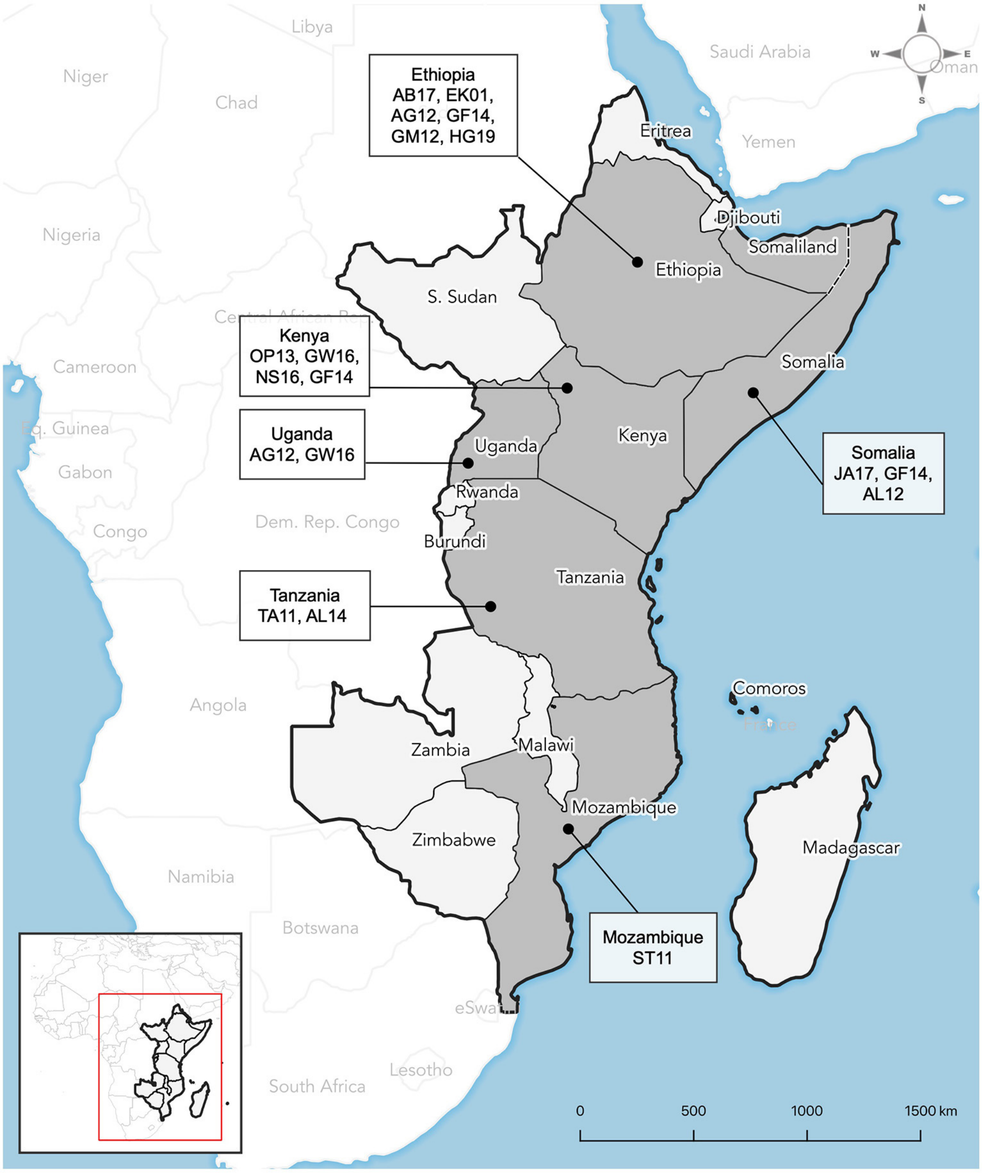

FIGURE 1 | Map of case study locations across East Africa. Dark grey indicates country case studies included in the review.

of climatic change factors and human mobility in East Africa. Applying the inclusion-exclusion criteria, the systematic literature review yields in 14 case studies published between 2000 and 2019 (see **Supplementary Figure 1**). For the analysis, we focus on country studies to cover large geographical areas in East Africa (**Supplementary Table 1**).

We apply a set of categories to the selected case studies, well-established in climate mobility research to systematically categorise the studies (Piguet, 2010). We synthesised evidence on socio-economic and political drivers which we hereafter refer to as contextual drivers as well as weather and climate-related drivers of human mobility (section Result). We then categorised the case studies according to the type of weather and climate-related event studied. To better understand the spatio-temporal dynamics of human mobility, we separately list the departure and arrival regions, and the analytical time horizon covered in the case studies. We also separately marked case studies which refer to multi-causality as a theoretical concept of human mobility (**Supplementary Table 2**).

Topic Model Approach

In a second analytical step, we apply a topic model approach on the selected case studies to classify them according to their key topics and word frequencies. The systematic literature review serves as statistical base for our model. Topic models are unsupervised machine learning techniques aiming at exploring text collections thematically. Our approach allows to generate topics through a set of statistical models that depict common

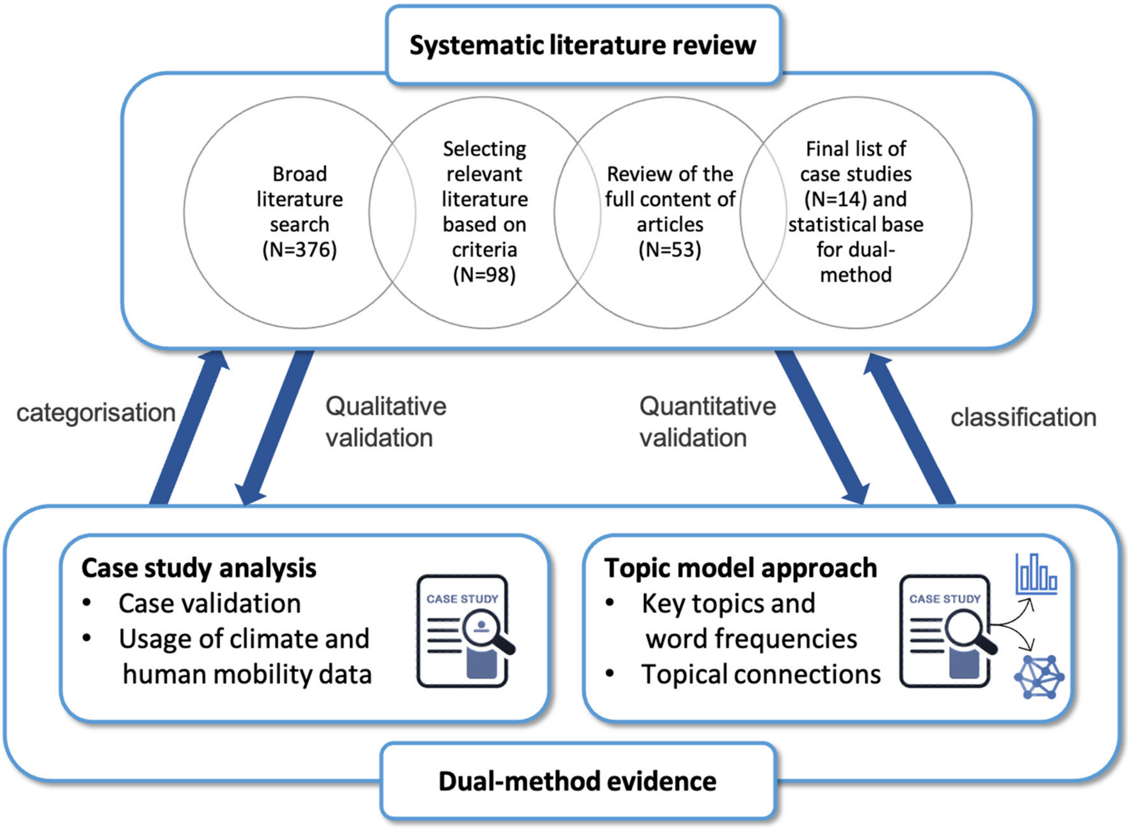

FIGURE 2 | Conceptual framework of the dual-method framework.

occurrences of words within and across the case studies. From the systematic literature review, we gather that all selected case studies are broadly about the topic of climate mobilities. Using the topic model approach, it is generally assumed that a text collection consists of different topics with a topic being understood to be a cluster of words; in this case words such as "climate," "migration," and "household" frequently occur together. Broadly, a topic can be regarded as a statistical phenomenon and therefore some correspondence, but not exactly the same as a (content-defined) theme. However, topic modelling methods are typically used to analyse large text collections (**Supplementary Section C**). We overcome the challenge of working with a smaller sample size by using contextual clues to connect words with similar meanings and distinguish between uses of words with multiple meanings. Topic models are therefore well-suited to explore the thematic contexts of a smaller sample size (Griffiths and Steyvers, 2004). Expanding on the results from the case study approach, topic models can help to discover hidden topical patterns that may be present across the case studies and might have been hidden otherwise. Hidden topical patterns can be revealed by annotating documents according to key topics; results of which we show in **Figure 3**. Using these annotations, topic modelling helps to organise, search and summarise the case studies. The method illustrates both the quantity and relevance of key terms. Thus, it is a well-suited approach to expand our understanding on the vast parameters contributing to climate mobilities.

RESULTS

Here, we use a dual-method evidence approach to investigate the drivers of human mobility, the role of climate data used, which could allow for any attributable links between extreme weather, human mobility, and anthropogenic climate change. Employing a diverse range of qualitative and quantitative methods, the case studies frame the influence of extreme weather on human mobility through basic plausible assumptions of push-pull factors: climatic stress conditions typify a push factor, and better economic opportunities a pull factor, for example. Showing multiple spatial and temporal dimensions of human mobility, these studies provide currently the best evidence on whether anthropogenic climate change and natural variability are currently influencing human mobility in East Africa.

Drivers of Human Mobility

As a region, East Africa is considered a hot-spot of compound events due to increased population exposure resulting from extreme weather and population growth (Weber et al., 2020). Although parts of the region are well-represented in the literature, the evidence on drivers of climate-related human

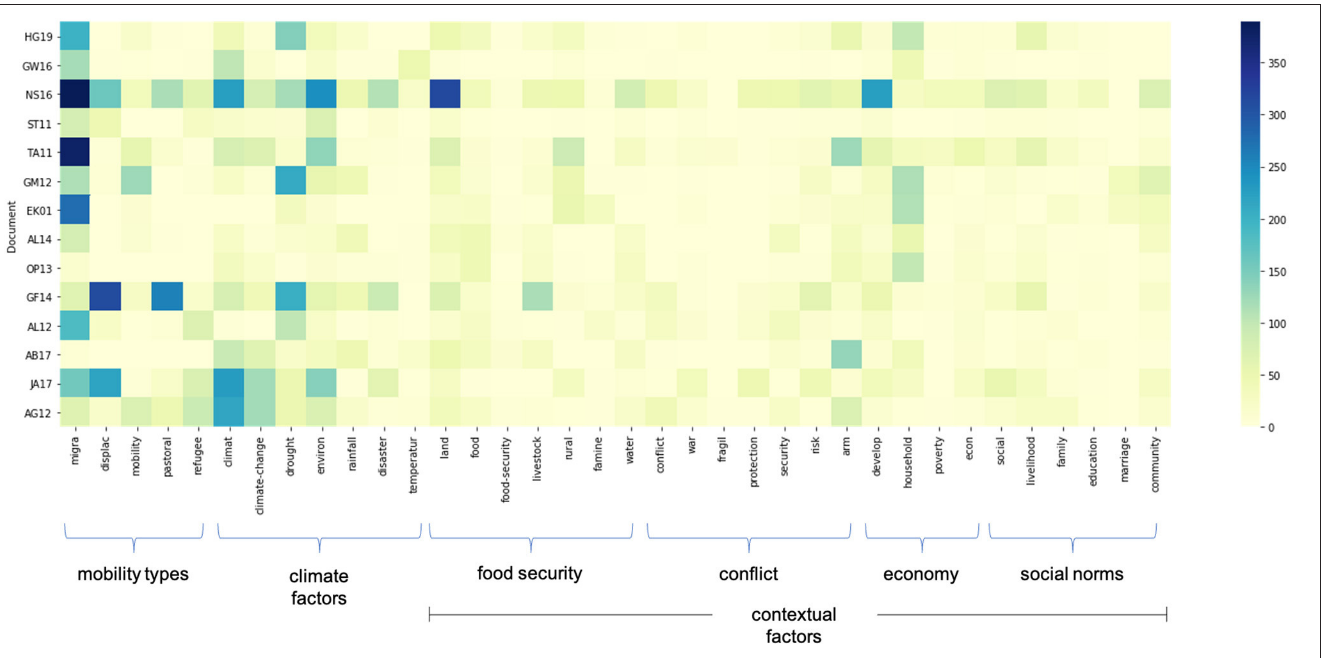

FIGURE 3 | Heatmap of word frequency illustrates the distribution of mobility types, climate, and contextual factors across the selected case studies. Contextual factors include four topics: conflict, economy, food security, and social norms. Each topic consists of five to eight keywords derived from a list of the 100 most frequent words.

mobility beyond voluntary migration, direct and indirect factors, and their interlinkages remain inconclusive and context-specific (van der Land et al., 2018; Groth et al., 2020).

Apart from the very diverse temporal (including permanent migration) and geographical scales on which human mobility takes place, there are different forms human mobility can take. We find that the case studies distinguish between voluntary forms of mobility (i) migration and (ii) pastoralism, and involuntary mobility (iii) displacement and iv) refugees, (v) asylum seekers and (vi) resettlement (**Table 1**).

Conversely, we find large differences on how studies analyse and describe a country or regional context (macro-level studies), e.g., employing models to control for specific socio-economic and contextual political variables to isolate the specific impact of climate on migration or investigating climate change perceptions of affected populations on the move through interviews. GM12 for example, investigates drought effects on local populations in Ethiopia through multivariate regressions (Gray and Mueller, 2012). AG12 (Afifi et al., 2012) provides evidence on climate change perceptions and vulnerability from the perspective of refugees based in camps in Ethiopia and Uganda.

Our topic model allows to disentangle weather and climate-related drivers in human mobility from contextual drivers. By adding this approach, we can further infer that the studies document and discuss various types, drivers and impacts (sub-themes) of human mobility in the study region (**Figure 3**, **Supplementary Figure 2**). The topic model reveals structures highlighting that a range of contextual factors regarding food security, economy, conflict, and social norms influence human mobility in addition to climate factors. Within these contextual factors, armed conflict, social norms, and livelihoods, e.g., pastoralism, and community stand out across all case studies (**Figure 3**).

Interestingly, the studies OP13 (Opondo, 2013), ST11 (Stal, 2011), AB17 (Alemayehu and Bewket, 2017) focus on a single factor influencing human mobility, whereas the other case studies use a framework proposed by Black et al. (2011), acknowledging the multi-causality in human mobility drivers. A multi-causal framework proves to be well-suited to conceptualise different geographical and temporal dimension of direct and indirect factors influencing human mobility (Groth et al., 2020). Several case studies used the framework as theoretical baseline to study the links between human mobility and weather and climate-related events, often in the context of loss and damages or economic vulnerability, e.g., EK01 (Ezra and Kiros, 2001), TA11 (Tacoli, 2011), and HG19 (Hermans and Garbe, 2019).

The Role of Climate Data

In light of limitations on human mobility data (Hauer et al., 2020), widely-available climate data takes a profound role in drawing conclusion on the effects of weather and climate-related events on human mobility and the potential links to anthropogenic climate change.

We find that at minimum, if at all, studies only use basic climate indicators to investigate climatic determinants of mobility. For example, publications around the Same-Kilimanjaro region in Tanzania (Afifi et al., 2014: AL14) or in (Nyaoro et al., 2016: NS16) use annual rainfall trends but forego to take the complexity of seasonality into account. One third of the case studies include climate data in their analysis or rely on

TABLE 1 | Topic map showing the distribution of mobility types and contextual factors across countries.

	Ethiopia	Kenya	Mozambique	Somalia	Tanzania	Uganda
Contextual topics by country	Drought, climate, household	Environment, land, development	Environment, climate, land	Climate, drought, risk	Environment, conflict, rural	Climate, climate change, environment
Mobility types by country	Migration	Migration	Migration	Displacement	Migration	Refugees

For each country, the mobility types identified from the literature are summed up and the most frequent types are shown.

TABLE 2 | Climate data used in case studies.

Reference	Climate data used	Time series	Type of extreme weather event	Dataset source
HG19	Daily precipitation data	1985–2015 (excluding 2014)	2015 Ethiopian drought	East Amhara Meteorology Service Center
GW16	Gridded climate data products from weather stations and reanalysis data (a) Climatic Research Unit (CRU) time series 3.21 for monthly rainfall and temperature data (b) Modern Era-Retrospective Analysis for Research and Applications (MERRA) for monthly mean land surface temperature and total surface precipitation	2009–2014 (Base period 1981–2010)	Climate variability	(a) UEACRU (b) NASA
GM12	Global daily precipitation from Prediction of Worldwide Energy Resources (POWER) data	1997–2009	2002 + 2008 Ethiopian drought	NASA
AL14	- Mean monthly absolute rainfall values and anomalies - Number of rain days per annum for the Same district.	- 1950–2010 - 1950–2000	Climate variability	Tanzania Meteorological Agency
OP13		N/S		
ST11		N/S		
AB17	- Monthly, seasonal, and annual rainfall totals - temperature (maximum and minimum)	- 1983–2013 - 1981–2011		Weather stations and meteorological satellite observations
JA17		N/S		
EK01		N/S		
GF14	- Monthly rainfall	2008–2013	Drought	N/S
NS16	- N/S			
AG12	Annual absolute, max and min temperature	1992–2011	Drought	Weather stations: - Ethiopia: Addis Ababa Bole weather station - Uganda: Entebbe Airport
AL12		N/S		
TA11		N/S		

N/S indicates that no climate data is used for the analysis.

previous publications of climate data assessments in the region, for example GF14 (Ginnetti and Franck, 2014), AG12 (Afifi et al., 2012), and AB17 (see **Table 2**). Of those, several use a single aspect of climatic change, such as rainfall anomalies (e.g., HG19) or temperature change (e.g., AB17) while others use historical precipitation data on different temporal scales such as monthly rainfall or minimum and maximum temperature (e.g., AB17, data from 1981–2013).

One case, Afifi et al. (AL14), uses monthly mean precipitation observations from the Tanzania Meteorological Agency (TMA) to describe changes in climate variability. They refer to annual mean temperature of 1992–2011 as a drought indicator of the 2011 East African drought. Alemayehu and Bewket (AB17) describe rainfall and temperature variability observations with results from their previous study that analysed average annual maximum and minimum temperatures from 1981 to 2013 (Alemayehu and Bewket, 2016). Interestingly, neither of these publications justify how temperature anomalies are linked to the occurrence of drought in the area. Instead, by analysing temperatures, the studies seem to imply that changing temperatures are a defining factor of drought. Yet, in an arid region it is usually rainfall that determines drought (Manning et al., 2018; Coughlan de Perez et al., 2019). Recent scientific studies suggest that temperature changes play a negligible role compared to other drivers of drought in East Africa (Philip et al., 2017; Kew et al., 2021).

Instead of analysing climate data, three studies use country-level records from the disaster statistics database EM-DAT (Guha-Sapir et al., 2016) to define an extreme weather event, for example, the 2002 and 2008 Ethiopian drought (GM12). Based on these records, NS16 lists the impacts of drought and flood disasters on affected populations from 1964 to 2015, whereas Stal (ST11) uses the database to define the two flood events investigated in the Zambezi River Valley. By incorporating satellite imagery of the 2001 flood and a risk assessment map for the 2007 flood, ST11 supports the characterisation of the event through physical characteristics of an extreme weather event (Stal, 2011).

Hermans and Garbe (HG19) investigate direct livelihood strategies, migration experiences and perceptions of the 2015 Ethiopian drought with household-level and individual information from a household survey and focus group discussions in early 2016, shortly after the drought ended. Despite framing the start and end of the drought by using a time series of 30-year daily rainfall observations (a triplet of 10-year blocks from 1985 to 1994, 1995 to 2004, and 2005 to 2014), the authors use the rainfall data to illustrate an increasingly variable start of the Belg rainy season across the time series through basic descriptive statistics.

Gridded climate datasets are used by a single case study of our document corpus. Gray and Wise (GW16) use observed monthly temperature and rainfall data from the Climatic Research Unit (CRU) in combination with NASA's MERRA reanalysis data on land surface temperature to address limitations identified in previous studies (see **Table 2**). They criticise the usage of a single climate dataset to explore links between climate variability and human migration (Gray and Wise, 2016).

All case studies focus on historical weather and human mobility; only GF14 also models future displacement with a systems dynamics model that aims to improve the understanding of root causes of lost livelihoods. Along livestock and displacement statistics, Ginnetti and Franck (GF14) compare 2008 to 2013 mean annual rainfall over Somalia, Kenya and Ethiopia with anecdotal, national-level monthly displacement records. This data serves as a proxy for drought and is mapped with socio-economic data such as agriculture productivity. On this basis, the resulting model produces estimates of drought-related displacement by 2040 that can be compared to empirical evidence of past displacement due to drought. In terms of extreme event definition, the study relies on existing reports for defining drought impacts on livestock during 1991 to 2010 rather than using drought indicators. However, it remains unclear why such data was chosen instead of metrics such as the Standartized Precipitation Evaporation Index (SPEI) or precipitation anomalies for which the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) dataset is well-suited (Dinku et al., 2018).

Human Mobility Data

All studies use a single mobility dataset for their analysis (**Supplementary Table 2**). A fact primarily resulting from the very limited availability of datasets on combined mobility types or simply due to time and budget constraints (e.g., ST11, EK01, AG12). Ezra and Kiros for example, list a range of data limitations to their household survey implementation, such as spatial and temporal elements of their survey design (EK01).

In terms of data sources, the four grey literature studies rely on locally collected mobility data over the span of a few weeks. NS16 use UNHCR-collected country-level data from 2016 on refugees from various East African countries, most of them originating from Somalia (71%) and South Sudan (16%). Similarly, Jayawardhan (JA17) uses the same data source for annual displacement from 2009 to 2012 to show a peak in drought-related displacement during the 2011 drought in Somalia (Jayawardhan, 2017). Ten case studies collected empirical mobility data through household surveys and interviews with government officials and population affected by extreme weather using common combinations of sample surveys and qualitative research methods (**Supplementary Table 2**) at either the source or destination area (e.g., OP13, AG12, AL14, and GM12). Only Tacoli (TA11) interviewed Maasai men, an increasingly mobile group, in both the origin (rural) and destination (urban) across Tanzania. AL14 uses a combination of empirical data that includes a survey of 165 households, expert interviews and focus group discussions. Herman and Garbe (HG19) differentiate between participants who return after a month or longer (temporary migrants), and those unlikely to return (permanent migrants) in their dataset and contextualises migration decisions of male household heads with focus group discussions of farmers in northern Ethiopia. The empirical studies use a combination of complementing methodologies to support the time frame of the analysis. The combination of sample surveys and qualitative research methods is common. AG12 use a mixed-method approach of expert interviews, household survey together with six participatory research methods to understand the interrelation between rainfall and mobility. Among affected populations, reported perceptions of climate stressors are fundamental for the definition and scope of extreme weather and help understand climate impacts experienced. These qualitative studies do not incorporate observational or reanalysis climate data, solely relying on perceived, and self-reported observations on climatic changes (see **Table 2**). This use of complimentary datasets on human mobility in AG12 is unique and sets apart the analytical validation. In contrast, three papers solely rely on secondary statistics from international organisations or non-governmental organisations such as UNHCR or FEWS Net (JA17, NS16, Achour and Lacan, 2012: AL12).

Implication of Anthropogenic Climate Change

To some extent, the studies base their analyses on the assumption that human-induced climate change has already affected mobility patterns in case study locations. It remains unclear whether case studies refer to human-induced climate change by defined by the UNFCCC (1992), or the evolution of local climate independent drivers which represents the Intergovernmental Panel on Climate

Change IPCC usage of the term 2018. Climate change is often discussed in the context of drought (e.g., JA17, AG12, and NS16). In particular, grey literature contextualises adverse impacts of climate change on sectors such as forestry (for example, ST11), agriculture, and livelihoods, like JA17 (**Figure 3**).

From a theoretical standpoint, the studies refer to indirect and direct drivers of human mobility as suggested by Black et al. (2011) in the context of climate change (**Supplementary Table 2**; **Figure 3**). For example, GF14 uses intervening facilitators for drought-related displacement in a dynamic model of livestock and market trends and estimates future dynamics of such displacement under climate change. AG12 specifically add the climate change component to migration in the initial data collection by including climate change perceptions across different groups of interviewees to understand its (perceived) role in out-migration. They find that refugees affected by climate variability directly link changes in climate to increases in political conflict and violence occurrences. GF14 make it clear that the study only links to trends in the climate independent of the cause by defining the term according to the definition provided by the IPCC. Synthesising the results of their systems dynamics model, emphasis is put on the multi-causality of human mobility drivers, particularly that drought and climate change (and/or variability) are not the only drivers of displacement.

DISCUSSION AND CONCLUSIONS

Our dual-method Review aimed at identifying whether the existing academic literature provides causal evidence for linking human mobility in East Africa with anthropogenic climate change. Our analysis consisting of a classical review of the existing literature and a topic model approach to further analyse published case studies leads us to the conclusion that this is not the case.

There are several reasons for this conclusion. To assess the existing literature, it is important to highlight that those contextual factors affecting human mobility are not evenly distributed across the study region but primarily exist in areas that experience drought and conflict; often reflecting the prominence of such reporting by humanitarian agencies: 75% of new displacements in 2019 are associated with weather and climate-related events and 25% with conflict and violence. Regionally, Sub-Saharan Africa tends to experience more conflict-related displacement than displacement triggered by extreme weather events (Internal Displacement Monitoring Centre, 2020). This further shows that the links between weather and climate-related events, contextual factors and human mobility are complex, defying simplistic reasoning according to which climate change would "lead" to human mobility. In fact, depending on the circumstances, climatic variability or extreme weather can lead to more, or less human mobility (Wiederkehr et al., 2018).

Furthermore, in many cases, regardless of the exact location investigated, the fact that human mobility is part of societies is not mentioned in the reviewed analyses. As such, displacement is discussed in conflict-affected Somalia, a country consisting of circa 60% pastoralists, a traditionally mobile part of the population that has long used migration as a coping mechanism in times of water scarcity or prolonged heat (Kassahun et al., 2008; Leal Filho et al., 2020). We find that the case studies are based on the implicit assumption that, generally, most people in a given location would prefer to stay where they live, as long as they have sufficient freedoms, are safe, and have economic opportunities. The results from the topic model emphasise that factors other than climate and weather, such as conflict, land use practises, and social norms, are believed to be important factors which contribute to forced migration flows in East Africa. Social science data, such as household surveys, are frequently used to support these claims. Despite nods to multi-causality, data on contextual drivers of human mobility are not further analysed. This lack of contextual data suggests an oversimplified conclusion on climate mobilities, an aspect that has also been identified in a review on environment-related migration in West Africa (van der Land et al., 2018).

Crucially, we find that the use of climate data in all studies is inconsistent if data is used at all. Those case studies that employ climate data use a diverse set of spatial and temporal variables motivated more by availability and ease of use than by the significance in defining the weather and climate-related events affecting the region. No climate data assessment in the reviewed studies provides causal evidence for a link between observed events and human-induced climate change.

Collectively, our results are consistent with evidence on contextual factors contributing to environment-related migration (Groth et al., 2020; Hoffmann et al., 2020) and expand the scope of findings by investigating links to anthropogenic climate change. While the lack of contextual data is often driven by availability, such limitations also exist for climate data (Otto et al., 2020). However, the relatively random or even unjustified choice of climate and weather data used in the reviewed case studies is still to question.

Our results shows that none of the ways this climate and human mobility data has been used allows to single out or disentangle anthropogenic drivers of changes in the data. Thus, there is not yet a basis to causally link anthropogenic climate change to human mobility in this region. However, all case studies published after 2010 (13 out of 14) mention or refer to human-induced climate change in a way that is very ambiguous and tends to imply a causal connexion. The grey literature studies depict (Achour and Lacan, 2012; Nyaoro et al., 2016) climate change as a tipping point for forced migration and conflict but uses inadequate methods and data to support such claims. Conversely, this suggests there is currently no evidence for a causal link between extreme events motivating human mobility in East Africa and anthropogenic climate change.

We acknowledge the geographical limitation of our results. Even though East Africa is vulnerable to the effects of future climate changes and also population developments, it has remained notoriously understudied (Harrington and Otto, 2020). Even with the results of the dual-method analysis in hand, the reviewed studies are also limited in scope and data used, often relying on secondary data.

What this review shows is that the evidence for East Africa is unfit to attribute human mobility to anthropogenic climate change. We do not show that such evidence is principally impossible to obtain, but highlight that a comprehensive understanding of the contribution of climatic factors influencing human mobility can only be achieved through a broad range of different, complimentary data. In turn, we argue, these data can only be understood and integrated by combining knowledge from very different disciplines. Whereas, we acknowledge the restrictions in human mobility data available, we propose to expand the integration of climate data in future studies on climate mobilities to capture impacts and human responses to weather and climate-related events.

Thus, to better understand the extent to which anthropogenic climate change plays a role in existing population movements in East Africa and globally, a new framework of interdisciplinary research is needed, which integrates diverse data into models that simulate how human mobility is impacted by contextual and climate change-related factors. From other parts of the world examples exist how climate and mobility data can be jointly assessed, using e.g., econometric methods to quantify the probability of climate change impacts (Castle and Hendry, 2020), outmigration as a result of disasters in multiple regions (Feng et al., 2010; Bohra-Mishra et al., 2014) or even to explore the climate-conflict-migration (Abel et al., 2019). Descriptive statistical methods allow for quantifying the link between past extreme weather events and human mobility. However, the second step, to identify whether and to what extent anthropogenic climate change was a driver of the extreme is missing across all studies and world regions (Beine and Jeusette, 2018). One promising way towards such a framework could be to combine the statistical methods to link weather and climate-related events and human mobility with extreme event attribution (EEA) (Horton et al., 2021). EEA comprises methodologies to understand whether and by how much anthropogenic climate change has contributed to the intensity and likelihood of extreme events (Stott et al., 2016). With extreme event attribution and econometric methods in hand, the ensuing decade is likely to bring new insights and further changes to our understanding on complex causalities and paradigms of human mobility and for the first-time causal evidence for the link between anthropogenic climate change and human mobility.

AUTHOR CONTRIBUTIONS

LT conducted all of the analysis and writing for this paper. SA and FO edited the manuscript. All authors discussed the methodology, results, and structure of the paper.

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SUPPLEMENTARY MATERIAL

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REFERENCES

Abel, G. J., Brottrager, M., Cuaresma, J. C., and Muttarak, R. (2019). Climate, conflict and forced migration. *Glob. Environ. Change* 54, 239–249. doi: 10.1016/j.gloenvcha.2018.12.003

Achour, M., and Lacan, N. (2012). *Drought in Somalia: A Migration Crisis*. Paris. 16.

Afifi, T., Govil, R., Sakdapolrak, P., and Warner, K. (2012). Climate change, vulnerability and human mobility: perspectives of refugees from the east and horn of Africa. *Climate Change* 60:1–60.

Afifi, T., Liwenga, E., and Kwezi, L. (2014). Rainfall-induced crop failure, food insecurity and out-migration in Same-Kilimanjaro, Tanzania. *Climate Dev.* 6, 53–60. doi: 10.1080/17565529.2013.826128

Alemayehu, A., and Bewket, W. (2016). Local climate variability and crop production in the central highlands of Ethiopia. *Environm. Dev.* 19, 36–48. doi: 10.1016/j.envdev.2016.06.002

Alemayehu, A., and Bewket, W. (2017). Smallholder farmers' coping and adaptation strategies to climate change and variability in the central highlands of Ethiopia. *Local Environ.* 22, 825–839. doi: 10.1080/13549839.2017.1290058

Bakewell, O. (2008). 'Keeping Them in Their Place': the ambivalent relationship between development and migration in Africa. *Third World Q.* 29, 1341–1358. doi: 10.1080/01436590802386492

Bakewell, O. (2010). Some reflections on structure and agency in migration theory. *J. Ethn. Migr. Stud.* 36, 1689–1708. doi: 10.1080/1369183X.2010.489382

Bastia, T., and Skeldon, R. (2020). *Routledge Handbook of Migration and Development*. New York, NY: Routledge. doi: 10.4324/9781315276908

Beine, M. A. R., and Jeusette, L. (2018). *A Meta-Analysis of the Literature on Climate Change and Migration (SSRN Scholarly Paper No. ID 3338771)*. Rochester, NY: Social Science Research Network.

Black, R., Adger, W. N., Arnell, N. W., Dercon, S., Geddes, A., and Thomas, D. (2011). The effect of environmental change on human migration. *Glob. Environ. Change* 21, S3–S11. doi: 10.1016/j.gloenvcha.2011.10.001

Bohra-Mishra, P., Oppenheimer, M., and Hsiang, S. M. (2014). Nonlinear permanent migration response to climatic variations but minimal response to disasters. *Proc. Natl. Acad. Sci. U.S.A.* 111, 9780–9785. doi: 10.1073/pnas.1317166111

Borderon, M., Sakdapolrak, P., Muttarak, R., Kebede, E., Pagogna, R., and Sporer, E. (2019). Migration influenced by environmental change in Africa: a systematic review of empirical evidence. *Demogr. Res.* 41, 491–544. doi: 10.4054/DemRes.2019.41.18

Byers, E., Gidden, M., Leclère, D., Balkovic, J., Burek, P., Ebi, K., et al. (2018). Global exposure and vulnerability to multi-sector development and climate change hotspots. *Environ. Res. Lett.* 13:055012.

Castle, J. L., and Hendry, D. F. (2020). Climate econometrics: an overview. *FNT Econ.* 10, 145–322. doi: 10.1561/0800000037

Cattaneo, C., Beine, M., Fröhlich, C. J., Kniveton, D., Martinez-Zarzoso, I., Mastrorillo, M., et al. (2019). Human migration in the era of climate change. *Rev. Environ. Econ. Policy* 13, 189–206. doi: 10.1093/reep/rez008

Collier, P., Conway, G., and Venables, T. (2008). Climate change and Africa. *Oxf. Rev. Econ. Policy* 24, 337–353. doi: 10.1093/oxrep/grn019

Coughlan de Perez, E., van Aalst, M., Choularton, R., van den Hurk, B., Mason, S., Nissan, H., et al. (2019). From rain to famine: assessing the utility of rainfall observations and seasonal forecasts to anticipate food insecurity in East Africa. *Food Sec.* 11, 57–68. doi: 10.1007/s12571-018-00885-9

Dinku, T., Funk, C., Peterson, P., Maidment, R., Tadesse, T., Gadain, H., et al. (2018). Validation of the CHIRPS satellite rainfall estimates over eastern Africa. *Quart. J. R. Meteorol. Soc.* 144, 292–312. doi: 10.1002/qj.3244

Ezra, M., and Kiros, G.-E. (2001). Rural out-migration in the drought prone areas of ethiopia: a multilevel analysis1. *Int. Migrat. Rev.* 35, 749–771. doi: 10.1111/j.1747-7379.2001.tb00039.x

Feng, S., Krueger, A. B., and Oppenheimer, M. (2010). Linkages among climate change, crop yields and Mexico–US cross-border migration. *Proc. Natl. Acad. Sci. U.S.A.* 107, 14257–14262. doi: 10.1073/pnas.1002632107

Flahaux, M.-L., and De Haas, H. (2016). African migration: trends, patterns, drivers. *Comparat. Migrat. Stud.* 4:1. doi: 10.1186/s40878-015-0015-6

Funk, C. (2020). Ethiopia, Somalia and Kenya face devastating drought. *Nature* 586:645. doi: 10.1038/d41586-020-02698-3

Ginnetti, J., and Franck, T. (2014). *Assessing Drought Displacement Risk for Kenyan, Ethiopian and Somali Pastoralists*. Geneva.

Gray, C., and Mueller, V. (2012). Drought and population mobility in rural Ethiopia. *World Dev.* 40, 134–145. doi: 10.1016/j.worlddev.2011.05.023

Gray, C., and Wise, E. (2016). Country-specific effects of climate variability on human migration. *Clim. Change* 135, 555–568. doi: 10.1007/s10584-015-1592-y

Griffiths, T. L., and Steyvers, M. (2004). Finding scientific topics. *Proc. Natl. Acad. Sci. U.S.A.* 101, 5228–5235. doi: 10.1073/pnas.0307752101

Groth, J., Ide, T., Sakdapolrak, P., Kassa, E., and Hermans, K. (2020). Deciphering interwoven drivers of environment-related migration – a multisite case study from the Ethiopian highlands. *Glob. Environ. Change* 63:102094. doi: 10.1016/j.gloenvcha.2020.102094

Guha-Sapir, D., Below, R., and Hoyois, P. (2016). *EM-DAT: The CRED/OFDA International Disaster Database [WWW Document]*. Available online at: URL https://wedocs.unep.org/handle/20.500.11822/16183 (accessed November 25, 2019).

Haas, H. de. (2008). The myth of invasion: the inconvenient realities of African migration to Europe. *Third World Q.* 29, 1305–1322. doi: 10.1080/01436590802386435

Haas, H. de. (2010). The internal dynamics of migration processes: a theoretical inquiry. *J. Ethn. Migr. Stud.* 36, 1587–1617. doi: 10.1080/1369183X.2010.489361

Harrington, L. J., and Otto, F. E. L. (2020). Reconciling theory with the reality of African heatwaves. *Nat. Clim. Chang.* 10, 796–798. doi: 10.1038/s41558-020-0851-8

Hastrup, K., and Olwig, K. F. (Eds.). (2012). *Climate Change and Human Mobility: Global Challenges to the Social Sciences*. Cambridge, New York, NT: Cambridge University Press. doi: 10.1017/CBO9781139235815

Hauer, M. E., Fussell, E., Mueller, V., Burkett, M., Call, M., Abel, K., et al. (2020). Sea-level rise and human migration. *Nat. Rev. Earth Environ.* 1, 28–39. doi: 10.1038/s43017-019-0002-9

Hermans, K., and Garbe, L. (2019). Droughts, livelihoods, and human migration in northern Ethiopia. *Reg. Environ. Change* 19, 1101–1111. doi: 10.1007/s10113-019-01473-z

Hoffmann, R., Dimitrova, A., Muttarak, R., Crespo Cuaresma, J., and Peisker, J. (2020). A meta-analysis of country-level studies on environmental change and migration. *Nat. Climate Change* 10, 904–912. doi: 10.1038/s41558-020-0898-6

Horton, R. M., Sherbinin, A., de Wrathall, D., and Oppenheimer, M. (2021). Assessing human habitability and migration. *Science* 372, 1279–1283. doi: 10.1126/science.abi8603

Ide, T., Brzoska, M., Donges, J. F., and Schleussner, C.-F. (2020). Multi-method evidence for when and how climate-related disasters contribute to armed conflict risk. *Glob. Environ. Change* 62:102063. doi: 10.1016/j.gloenvcha.2020.102063

Internal Displacement Monitoring Centre (2020). *Global Report on Internal Displacement.* Geneva.

IPCC (2018). *Annex I: Glossary [WWW Document]*. Available online at:URL https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_AnnexI_Glossary.pdf (accessed October 20, 2020).

Jayawardhan, S. (2017). Vulnerability and climate change induced human displacement. *J. Sustain. Dev.* 17, 103–142. Available online at: https://www.jstor.org/stable/26188784

Kassahun, A., Snyman, H. A., and Smit, G. N. (2008). Impact of rangeland degradation on the pastoral production systems, livelihoods and perceptions of the Somali pastoralists in Eastern Ethiopia. *J. Arid Environ.* 72, 1265–1281. doi: 10.1016/j.jaridenv.2008.01.002

Kelley, C. P., Mohtadi, S., Cane, M. A., Seager, R., and Kushnir, Y. (2015). Climate change in the Fertile Crescent and implications of the recent Syrian drought. *Proc. Natl. Acad. Sci. U.S.A.* 112, 3241–3246. doi: 10.1073/pnas.1421533112

Kew, S. F., Philip, S. Y., Hauser, M., Hobbins, M., Wanders, N., Oldenborgh, G. J., et al. (2021). Impact of precipitation and increasing temperatures on drought in eastern Africa. *Earth Syst. Dynam. Discussions* 12, 1–29. doi: 10.5194/esd-2019-20

Klepp, S. (2017). *Climate Change and Migration*. Oxford Research Encyclopedia of Climate Science, Oxford. doi: 10.1093/acrefore/9780190228620.013.42

Leal Filho, W., Taddese, H., Balehegn, M., Nzengya, D., Debela, N., Abayineh, A., et al. (2020). Introducing experiences from African pastoralist communities to cope with climate change risks, hazards and extremes: fostering poverty reduction. *Int. J. Disaster Risk Reduct.* 50:101738. doi: 10.1016/j.ijdrr.2020.101738

Lugli, F., Cipriani, A., Capecchi, G., Ricci, S., Boschin, F., Boscato, P., et al. (2019). Strontium and stable isotope evidence of human mobility strategies across the Last Glacial Maximum in southern Italy. *Nat. Ecol. Evol.* 3, 905–911. doi: 10.1038/s41559-019-0900-8

Manning, C., Widmann, M., Bevacqua, E., Van Loon, A. F., Maraun, D., and Vrac, M. (2018). Soil moisture drought in europe: a compound event of precipitation and potential evapotranspiration on multiple time scales. *J. Hydrometeor*. 19, 1255–1271. doi: 10.1175/JHM-D-18-0017.1

Marthews, T. R., Jones, R. G., Dadson, S. J., Otto, F. E. L., Mitchell, D., Guillod, B. P., et al. (2019). The impact of human-induced climate change on regional drought in the horn of Africa. *J. Geophys. Res.* 124, 4549–4566. doi: 10.1029/2018JD030085

Nyaoro, D., Schade, J., and Schmidt, K. (2016). *Assessing the Evidence: Migration, Environment and Climate Change in Kenya (report).* Geneva: International Organization for Migration.

Opondo, D. O. (2013). Erosive coping after the 2011 floods in Kenya. *Int. J. Glob. Warm.* 5, 452–466. doi: 10.1504/IJGW.2013.057285

Otto, F. E. L., Harrington, L. J., Frame, D., Boyd, E., Lauta, K. C., Wehner, M., et al. (2020). Towards an inventory of the impacts of human-induced climate change. *Bull. Amer. Meteor. Soc.* 101, 1–17. doi: 10.1175/BAMS-D-20-0027.1

Philip, S., Kew, S. F., van Oldenborgh, G. J., Otto, F. E. L., O'Keefe, S., Haustein, K., et al. (2017). Attribution analysis of the ethiopian drought of 2015. *J. Climate* 31, 2465–2486. doi: 10.1175/JCLI-D-17-0274.1

Piguet, E. (2010). Linking climate change, environmental degradation, and migration: a methodological overview. *Wiley Interdiscip. Rev. Climate Change* 1, 517–524. doi: 10.1002/wcc.54

Randall, A. (2015). "Mobilizing action on climate change and migration," in *Organizational Perspectives on Environmental Migration*, eds K. Rosenow-Williams and F. Gemenne (London: Routledge), 16.

Rigaud, K. K., De Sherbinin, A., Jones, B., Bergmann, J., Clement, V., Ober, K., et al. (2018). *Groundswell: Preparing for Internal Climate Migration*. Washington, DC: World Bank. doi: 10.1596/29461

Shongwe, M. E., van Oldenborgh, G. J., van den Hurk, B., and van Aalst, M. (2011). Projected changes in mean and extreme precipitation in Africa under global warming. Part II: East Africa. *J. Climate* 24, 3718–3733. doi: 10.1175/2010JCLI2883.1

Stal, M. (2011). Flooding and relocation: the Zambezi river valley in Mozambique. *Int. Migrat.* 49, e125–e145. doi: 10.1111/j.1468-2435.2010.00667.x

Stott, P. A., Christidis, N., Otto, F. E. L., Sun, Y., Vanderlinden, J.-P., van Oldenborgh, G. J., et al. (2016). Attribution of extreme weather and climate-related events. *Wiley Interdiscip. Rev. Climate Change* 7, 23–41. doi: 10.1002/wcc.380

Tacoli, C. (2011). *Not Only Climate Change: Mobility, Vulnerability and Socio-economic Transformations in Environmentally Fragile Areas in Bolivia, Senegal and Tanzania*. London: IIED.

Uhe, P., Philip, S., Kew, S. F., Shah, K., Kimutai, J., Mwangi, E., et al. (2018). Attributing drivers of the (2016). Kenyan drought. *Int. J. Climatol.* 38, e554–e568. doi: 10.1002/joc.5389

UNFCCC (1992). *United Nations Framework Convention on Climate Change*. New York, NY.

van der Land, V., Romankiewicz, C., and van der Geest, K. (2018). "Environmental change and migration: a review of West African case studies," in *Routledge Handbook of Environmental Displacement and Migration*, eds R. McLeman and F. Gemenne, 163–177.

Weber, T., Bowyer, P., Rechid, D., Pfeifer, S., Raffaele, F., Remedio, A. R., et al. (2020). Analysis of compound climate extremes and exposed population in Africa under two different emission scenarios. *Earth's Future* 8:e2019EF001473. doi: 10.1029/2019EF001473

White, A., Laoire, C. N., Tyrrell, N., and Carpena-Méndez, F. (2011). Children's roles in transnational migration. *J. Ethn. Migr. Stud.* 37, 1159–1170. doi: 10.1080/1369183X.2011.590635

Wiederkehr, C., Beckmann, M., and Hermans, K. (2018). Environmental change, adaptation strategies and the relevance of migration in Sub-Saharan drylands. *Environ. Res. Lett.* 13:113003. doi: 10.1088/1748-9326/aae6de

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