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An inventory tool to assess displacement data in the context of weather and climate-related events

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ABSTRACT

Weather and climate-related events have already altered human mobility patterns and led to displacement. While the evidence base is low due to data gaps and scarcity, climate change is expected to reinforce disaster-related displacement. Here we systematically analyze how components of internal displacement data are related to disaster outcomes in Somalia, Afghanistan, the Marshall Islands and Bangladesh using a data inventory tool. We contribute the first programmatic approach to evaluate the evidence of extreme weather impacts on internal displacement in four distinct case studies. We find that the data evidence differs considerably from the disaster displacement process recorded qualitatively in reports. We provide a straightforward, bottom-up application guide that ultimately improves the understanding of changing disaster displacement risks for researchers and practitioners alike. We thereby show nuances in data availability and granularity for potential causal statements between climate change and internal displacement. We conclude that the implementation of data-focused climate policy and action could address obstacles to averting and minimizing disaster displacement.

1. Introduction

Almost 95 million people are involuntarily on the move across the globe. A great portion of them are internally displaced populations (IDPs) (UNHCR, 2021). In 2021 alone, there were 38 million new internal displacements (IDMC, 2022d). Internal displacement is a term used to describe people forced to move within a country due to reasons such as conflict, violence and extreme weather events, e.g., droughts and floods (Kalin, 2008). Weather and climate-related events and the increasing concentration of populations in areas vulnerable to climate change mean that ever more people are at risk of displacement, as stated with “high confidence” in the latest IPCC WGII (2022) report chapters 7,8,10,16 (Pörtner et al., 2022). A recent study estimates an increase of about 50 percent in the “global displacement risk” for every degree of warming, and even more if the projected increase in population is factored in (Kam et al., 2021). In 2021, weather and climate-related events already accounted for around 90 percent of the recorded internal displacement (IDMC, 2022d). More and more, climate change impacts, both slow- and rapid-onset, adversely affect habitability and climate-dependent livelihoods (Horton et al., 2021). Already, impacts from climate change have accelerated internal displacement and rural–urban migration (Cattaneo et al., 2019; Hoffmann et al., 2020; Sedova & Kalkuhl, 2020). Addressing

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displacement is a key dimension of habitability and climate action (Horton et al., 2021). Yet, more can be done to understand the data dimension to be able to inform evidence-based climate policies and efforts of loss and damage (L&D).

Data challenges and knowledge gaps hamper progress in responding to displacement risks effectively, despite a considerable growth of the data landscape on displacement linked to weather and climate-related events (disaster displacement) (IDMC, 2021a; IOM, 2022a). Challenges range from sparse data availability to its quality and accessibility, different approaches to data collection and public accessibility (Task Force on Displacement, 2018). There is a need to systematically take inventory of existing displacement data in the weather and climate-related event context to provide a global baseline of disaster displacement risk. Thus far, efforts to extend the data landscape have not connected to efforts in minimizing displacement risk and preparing populations in situ before a natural hazard materialized (IOM & IDMC, 2022). Here, we set out an approach for assessing a set of recorded displacement events and associated weather and climate-related events in a programmatic inventory to better utilize displacement data in real time at local scales where impacts from extreme weather occur.

Addressing disaster displacement will require significant humanitarian, development, and interdisciplinary scientific measures (IFRC, 2020). However, resources are becoming increasingly stretched to service a growing number of humanitarian emergencies from weather and climate-related events. The Internal Displacement Index Report 2021 highlights that displacement datasets are scarce without a systematic overview to date in most countries (IDMC, 2021b). This scarcity calls for a comprehensive approach to investigate existing evidence on disaster displacement. Here, we contribute an inventory tool to assess the quality of displacement data in the context of weather and climate-related events. We focus on four countries that frequently experience droughts or floods and subsequent displacement: Somalia, Bangladesh, Afghanistan and the Marshall Islands (Hoffmann, 2022). Such an inventory approach can directly help to mitigate and reduce the risk of medium and long-term displacement by revealing crucial gaps in the data landscape and intervention points for programmatic disaster risk responses and preventative humanitarian action (Task Force on Displacement, 2018; Thalheimer et al., 2022). The development of the inventory tool is guided by a policy-relevant research question: What are the current data-related gaps and limitations in disaster-displacement research? We discuss applicable types of statistical analysis and modeling in the cases of low- and medium-quality displacement data availability. To our knowledge, this is the first inventory analysis in the climate mobility field conducted for a set of disaster displacement cases.

2. Disaster displacement data landscape

Several studies, including the 2022 IPCC Working Group II report, highlight the scarcity of human mobility data, in particular, migration and displacement data at a granular level (Abel et al., 2019; Hoffmann et al., 2021; Pörtner et al., 2022; Thalheimer et al., 2021). National authorities, international organizations, and non-governmental organizations (NGOs) record estimates for disaster displacement in several regions. However, their spatio-temporal coverage varies. Standardized measurements and indicators to capture the relevance of displacement do currently not exist despite their importance for disaster risk reduction (DRR) planning and implementation (IOM & IDMC, 2022). This section illustrates several open-source displacement datasets from different organizations.

2.1. Internal Displacement Monitoring Centre

The Internal Displacement Monitoring Centre (IDMC) tracks internal displacements by events including disasters and conflict to assist in analyzing and producing estimates based on the location, date of the incident, and triggers (IDMC, 2022b). This database accounts for two metrics, i) an occurrence of movement as a “flow” in the given time frame and ii) the total number of IDPs—populations in internal displacement as a “stock” at the end of the year. Notably, the IDMC database does not capture the duration of displacement. The collection of displacement data is available on the IDMC portal aggregated by the country and by the disaster event. Most displacement data is retrospective. Efforts to quantitatively predict displacement risk (Ginnetti & Franck, 2014) have been used to inform disaster displacement country profiles (IDMC, 2023b). Building on a range of hazard scenarios, IDMC displacement risk models calculate the likelihood of causing housing damage, a proxy used for displacement (IDMC, 2022c). IDMC data has been used to indicate trends in regions of disaster displacement risk relative to the population (Hoffmann, 2022). Data within IDMC may be of different quality depending on the country where the data is collected. For example in the Marshall Islands, data is only available for flood-related displacement while for Somalia, IDMC provides estimates for four disaster categories: drought, flood, storm and wildfires (IDMC, 2023a). This may be the case as IDMC is in part using data from another provider such as an international organization.

2.2. International Organization for migration – Displacement tracking Matrix

The Displacement Tracking Matrix (DTM) provided by the International Organization for Migration (IOM) is “a system to gather and analyze data to disseminate critical multi layered information on the mobility, vulnerabilities, and needs of displaced and mobile populations that enables decision makers and responders to provide these populations with better context specific assistance” (IOM, 2022b). DTM offers open-access records on location-specific estimates of conflict- and disaster-driven displacement in over 80 countries (IOM, 2022b; IOM DTM, 2018). There are four DTM components selectively applicable in the research according to the objectives: mobility tracking, flow monitoring, registration, and surveys. More detailed information on each component is available in Sections 4 and 5 of IOM’s Methodological Framework (IOM, 2022b).

In addition, location-level estimates of the most recent displacement are illustrated through an interactive map (International Organization for Migration, 2022b). IOM DTM also provides several country-specific qualitative reports that accompany these data points (International Organization for Migration, 2022a).

2.3. Other United Nations agencies

The UN High Commissioner for Refugees (UNHCR) works on population movement issues, asylum seekers, refugees and IDPs. UNHCR developed the Refugee Data Finder (UNHCR, 2023) to disaggregate displacement flows by demography variables such as country, sex, and age. UNHCR collects localized displacement data within an affected country. In Somalia, the Protection and Return Monitoring Network (PRMN) surveys heads of displaced households at various locations across all 74 districts about their primary reason for displacement and lists associated priority humanitarian needs (water, food and shelter) (UNHCR Somalia, 2017). The dataset offers a continuous time series from January 2016 to the near-present (UNHCR, 2022b).

The UN Office for the Coordination of Humanitarian Affairs (OCHA) is another subdivision that works on displacement-related issues at local, regional, and country levels to secure and aid IDPs. As a theme of interest, it published several reports on internal displacement and collected IDP-related data. For example, OCHA Türkiye shares monthly Syrian IDP and return flows between 14 governorates (states at administrative level 1) from 2016 to 2020 (OCHA, 2023). The data cannot be disaggregated by demography. Summaries of IDP movements are offered at the monthly level.

Notably, levels of data disaggregation vary by UN agency and country, i.e., displacement data of country A from one UN agency may have a different data disaggregation compared to the data of country B from the same agency.

3. Methods and data

3.1. Inventory tool

The interaction of weather and climate-related events with other human mobility drivers (e.g., social ties, conflict, economic) can be multi-directional and result in various displacement outcomes (McLeman et al., 2021). We illustrate how to assess the confidence of displacement estimates in Fig. 1, which subsequently guides our diagnostic identification strategy for this complex topic. Thereby, this paper develops a new framework to improve the understanding of weather and climate-related events impacts on displacement and differs from existing inventory tools that purely focus on the natural hazard side, e.g., Clarke et al., 2021, Otto et al., 2020.

While weather and climate-related events may directly drive displacement, there might be several consecutive or combined factors that indirectly drive displacement outcomes, highlighting the topic's complexity. To test our diagnostic framework and perform an

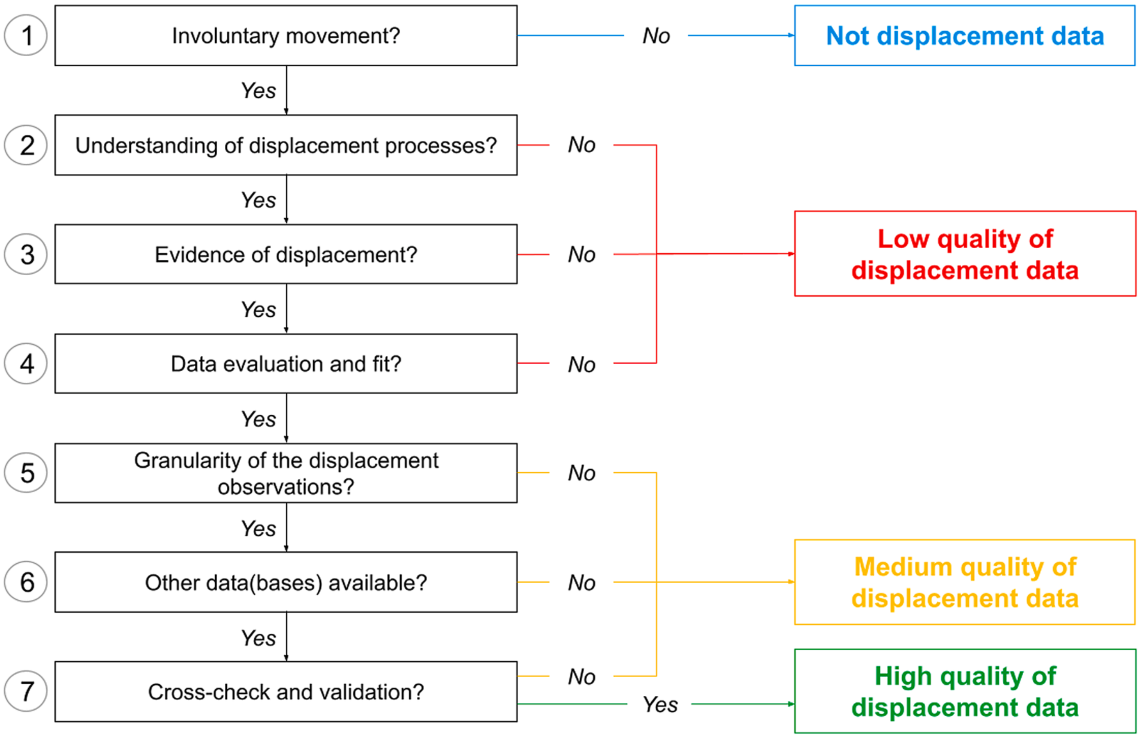

Fig. 1. Flowchart depicting the reasoning process to identify the quality of evidence in displacement datasets. Red arrows depict low quality, orange indicates medium quality, and green represents high quality. Note: Additional data sources should be cross-checked and validated. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

inventory, we focus on the impacts from weather and climate-related events. We gather datasets on reported displacement due to disasters and conflict in four locations. By analyzing how these data differ regarding granularity, spatio-temporal coverage, and reasons for displacement, we shed light on the quality of the displacement evidence. Examining data quality is crucial for the design of climate and security policy measures that can strengthen vulnerable populations and IDPs' resilience to extreme weather events to potentially minimize displacement risks and outcomes. In this context, we argue that formulating effective policy responses to the climate crisis requires an understanding of the interaction between the multi-causal drivers of displacement at the local level, i.e., where natural hazards materialize.

3.2. Inventory format

To assess the inventory of displacement data points, we start with a quality check as suggested by the IPCC guidance document (Mastrandrea et al., 2010). By applying a step-by-step diagnostic tool, we assess the quality of displacement data (Fig. 1). We illustrate seven assessment steps and decision points to rank the quality of available evidence on disaster displacement in a region or country as low, medium, and high. For the application of the tool, we utilize four displacement datasets in Somalia, Afghanistan, the Marshall Islands, and Bangladesh. The result of this quality assessment, based on expert judgements whether (yes) or not (no) the decision criteria have been met by the respective dataset, is depicted on the right side of Fig. 1.

The seven assessment steps are as follows:

1) *Involuntariness of mobility*: Is there evidence about different forms of forced mobility, for example, is there a recorded history of internal displacement due to external forces such as extreme weather, violence, or conflict?
2) *Displacement process understanding*: Process understanding refers to disaster impacts on displacement, e.g., the number of displaced populations by weather and climate-related events. Which type of mobility is addressed and does it fit the disaster impact? Data that estimates populations forcibly displaced due to extreme weather events can be regarded as disaster displacement data. Without an understanding of disaster displacement processes, it is impossible to disentangle extreme weather from other displacement drivers, e.g., economic and conflict drivers of forced mobility (Black et al., 2013).
3) *Multiple lines of evidence*: There should be evidence of a correlation between disaster and displacement, i.e., is there evidence that extreme weather drives displacements? Early migration scholarship often uses single-modeled or rough estimates, making it difficult to know whether displacement results are correlated with a particular extreme weather event (Boas et al., 2019). In the case of assessments based on recorded observations, existing lines of evidence often use a single data source to show the connection between the extreme weather event and displacement outcomes (e.g., Hoffmann et al., 2020, Hoffmann et al., 2021, Sedova & Kalkuhl, 2020).
4) *Fit for purpose*: Does the dataset report displacement estimates as opposed to other types of human mobility, for example, voluntary migration? If displacement is the focus, the dataset can be seen as fit for the purpose to evaluate disaster displacement. This step can include a cross-check for additional data sources as outlined in step 7.
5) *Granularity of the data used*: This includes the level of temporal and spatial granularity, reasons for displacement. Is the data disaggregated by gender, age, and other descriptive variables relevant to disaster displacement?
6) *Use of multiple databases or models*: Do several datasets exist in the given country, for example, IDMC data, UN OCHA data, and UNHCR data? Were there multiple models developed with the respective databases?
7) *Validation and cross-check*: The last step checks whether the data was validated or cross-checked with other available displacement and migration datasets for the (statistical) robustness of the results. The robustness can also be tested by comparing displacement databases with disaster databases, e.g., the Emergency Events Database (EM-DAT) and conflict databases, e.g., the Armed Conflict Location & Event Data Project (ACLED) (Raleigh et al., 2010). Are comparative data sources available? Is there qualitative data such as reports available that align or contextualize with the evidence from quantitative data?

3.3. Data and displacement patterns

Next, we apply the four datasets from four data providers to illustrate the inventory approach. By diversifying the dataset sources geographically, as well as the estimation, and data provider of each case study, we offer insights into different steps in the inventory tool.

3.3.1. Somalia

Somalia has been affected by protracted conflict and consecutive drought events that have led to large-scale displacement over the past thirty years. Back-to-back drought events have caused food insecurity and drinking water shortages, leaving an already vulnerable population even more vulnerable to the impacts of climate change (Maystadt and Ecker, 2014, OCHA, 2021, Thalheimer et al., 2023). The UN OCHA reported that "Somalia is experiencing a worsening drought following three consecutive failed rainy seasons and is at risk of a fourth consecutive underperforming rainy season in 2022" (OCHA 2021). Already at the onset of the East Africa drought in 2011, flood events already stretched fragile levels of wellbeing with damages to an already-poor infrastructure (FSNAU, 2011).

The severity of internal displacement in Somalia is also acute in overcrowded IDP settlements. UNHCR/PRMN publishes estimates on new internal displacements associated with conflict, drought, and flood (UNHCR, 2022b). The location-disaggregated dataset is updated regularly. The online version provides disaggregated data on location (region and district levels which are administrative levels 1 and 2), time (weekly and monthly), reported reasons for displacement (drought-related, flood, conflict/insecurity, other), and associated primary needs at the destination location (food, health, humanitarian aid, livelihood support, protection, shelter, transport, water, other). A disaggregation by sex and age is not available through PRMN but is available in qualitative data sources such as the 2021 Internal Displacement Index Report (IDMC, 2021b).

3.3.2. Afghanistan

Afghanistan's climate varies due to its topography from arid to semi-arid in the northeastern regions with Hindokosh Mountains to desert conditions in the southwestern regions (Haritashya et al., 2009, Qutbudin et al., 2019). The country is vulnerable to recurrent extreme weather, in particular, floods and droughts (Ranghieri et al., 2017). The economic status and socio-political instability aggravate the impacts of extreme weather events. In the long term, Afghanistan is expected to experience worsening conditions of natural hazards, particularly from droughts and floods (Qutbudin et al., 2019).

After years of conflict and environmental degradation, the severity of internal displacement is profound (IDMC, 2021b). Conflicts have been a major reason for internal displacement, driving approximately ten times more displaced populations than disaster-induced IDPs in 2017 and between 2019 and 2021. One exception was the year 2018 when severe droughts exacerbated pre-existing vulnerabilities of people to move and drought accounted for 53.9 percent of yearly IDPs (IDMC, 2019). The Ministry of Refugees and Repatriations works with the UN OCHA and IOM DTM to collect data on internal displacement on the sub-national level. The dataset is updated routinely (every 3–6 months) at the settlement level (the smallest administrative level). It is available by location, the number of returnees and IDPs, the major reason for the IDP in/outflow and accommodation type per each settlement.

3.3.3. Marshall Islands

The Marshall Islands are recurrently affected by floods and the impacts of sea level rise (van der Geest et al., 2020). IDMC records three distinctive flood-related displacement events between 2008 and 2021. Even though estimates of newly displaced people are relatively low (2,046 IDPs) compared to those of other regions, the Marshall Islands make an interesting case for impact attribution, since all recorded displacement resulted from flood events (IDMC, 2022c, p. 9). Drought-related displacement flows are currently not recorded. IDMC recognizes that "drought has had a severe impact on the population because most freshwater supplies and subsidence agriculture depend on rainfall." (IDMC, 2022c, p. 10). The IDMC data on internal displacement lists a single variable which is an estimate of IDP flows due to flooding.

3.3.4. Bangladesh

Bangladesh has continuously suffered from extreme rainfall and consecutive flooding events (Khan et al., 2021). In 2020, extreme weather events were the main driver of displacement, exacerbated by the COVID-19 pandemic (Thalheimer, 2022). Cyclone Amphan in late May resulted in 2.5 million displacements, the majority of which were pre-emptive evacuations to cyclone shelters. The monsoon floods, which were the worst in decades, inundated a quarter of the country by late July (NASA, 2020). These disasters led to approximately 1.9 million displacements in Chittagong, Sylhet, Dhaka, Rangpur, and Mymensingh divisions. In total, disasters resulted in 4.4 million new displacements in 2020, while inter-communal violence led to 230 new displacements (IDMC, 2021a). The National Strategy on the Management of Disaster and Climate-Induced Internal Displacement stipulates that the Ministry of Disaster Management and Relief should develop a national displacement tracking system and register IDPs. There is, however, no systematic national data collection system to date (IDMC, 2021b).

The Bangladesh Integrated Household Survey (BIHS), collected by the International Food Policy Research Institute (IFPRI), captures disaster-driven movements in Bangladesh at a household level, collected in three survey rounds during the periods of 2011–12, 2015, and 2018–19. The data is used in climate change impact studies including displacement and food security outcomes (Ahmed, 2015, Islam et al., 2018, Mallick et al., 2017, Sununtnasuk and Fiedler, 2017). BIHS includes a set of variables relevant to disaster displacement. BIHS Module V collects which member of the household migrated, the time of migration and associated socio-demographic variables (age, sex, education), destination country (for international migration/displacement), migration agency, and remittances.

4. Results

To illustrate how the inventory tool (see Fig. 1) can be used in practice, we consider four dataset examples that had considerable disaster displacement outcomes (see Table 1). We find large differences in weather and climate-related internal displacement data

Table 1
Overview of the disaster displacement records used in this study.

Location	Dataset source	Time range	Associated displacement drivers	Estimation method
Somalia	UNHCR/PRMN (2022b)	2016-present	drought, flood	disaggregated survey
Afghanistan	IOM DTM (2022a)	2017–2021	drought, conflict	survey
Marshall Islands	IDMC (2023b)	2008–2021	flood	secondary data collection (through report consolidation)
Bangladesh	IFPRI (2021)	2011–2012, 2015, 2018–2019 (three rounds)	drought, flood	national survey

quality across the datasets.

4.1. Somalia UNHCR/ PRMN data (HIGH)

1) UNHCR/ PRMN provides several records of internal displacement. First, there is a granular, disaggregated internal displacement dataset that provides quantitative insights. UNHCR also provides reports that contextualize displacement (qualitative insights).
2) According to the UNHCR/ PRMN dataset, the reported reasons for displacement are myriad and include a set of primary reasons including flood, drought, and conflict. These contribute to an understanding of the displacement processes. Contextual evidence exists in reports of various UN agencies.
3) The data is qualitatively assessed in several reports. Hoffmann Pham and Luengo-Oroz (2022) use a machine-learning platform approach to assess the predictive power of the UNHCR/PRMN data.
4) Yes, it reports internal displacement and is fit for purpose.
5) The UNHCR/PRMN data is disaggregated by displacement reason, providing different spatial (district and region) and time scales (week, month) of internal displacement since 2016.
6) There are other datasets on internal displacement in Somalia available: there are yearly figures of conflict and extreme weather-related internal displacement provided by IDMC and annual refugee flows by UNHCR (2022a).
7) Hoffman Pham and Luengo-Oroz (2022) do a data validation through robustness checks.

4.2. Afghanistan IOM-DTM data (LOW/MEDIUM)

1) The dataset focuses on displacement by disasters and conflicts indicating the involuntariness of mobility. Afghans were displaced by political instability and continuous conflicts since the late 1970 s (Přívara & Přívarová, 2019). Afghanistan is also exposed to varying weather and climate-related events such as high temperatures, droughts, and floods (Holloway et al., 2022). Particularly in 2018, rainfall deficit and snow melt led to crop failures and livestock casualties in northwestern rural provinces (Badghis, Ghor, and Herat), eventually leading to crop failures and livestock casualties (IDMC, 2019, Přívara and Přívarová, 2019).
2) IDPs in Afghanistan are mostly driven by socio-political conflicts rather than weather or climate-related events in 2017–2021 data collection except for 2018 (IDMC, 2019). The populations of conflict-induced IDPs took 94.6, 46.1, 79.8, 89.8, and 96.7 percent in 2017–2021. Thus, data for 2017 and 2019–2021 does not pass this step (LOW quality) and 2018 data pass this step. DTM data in Afghanistan collected whether the IDPs experienced disasters in Community Based Needs Assessments from the year 2018 (only for May-June 2018).
3) Yes. The baseline assessment at the settlement level offers the reasons to move into new locations and flee from their residence at the settlement level. Moreover, there is evidence of the correlation between disaster and displacement from existing studies (e.g., Přívara & Přívarová, 2019, Walton et al., 2021).
4) Yes, it reports internal displacement and is fit for purpose.
5) DTM data have baseline assessments at district and settlement spatial levels. In 2018, the temporal scales could be disaggregated into four rounds (January to March, April to June, June to September, and September to December). The data can also be categorized by displacement reason and accommodation type.
6) IDMC provides disaster-induced IDP data with the hazard type and IDP populations while it is not disaggregated into finer administrative levels. Tai et al. (2022) estimated internal displacement in Afghanistan using mobile phone data but was limited to internal displacement in 2019 (MEDIUM quality for IOM DTM data in 2018). An alternative dataset is the Multi-Sector Rapid Assessment System Database (IOM, 2023) which focuses on disaster displacement event records.
7) Tai et al. (2022) compared their internal displacement estimations with IOM DTM data in October-December 2019 for validation. However, the data still needs more effort in validation, cross-check, and robustness test. IOM publishes reports along with DTM data to illustrate qualitative and contextual features of internal displacement in Afghanistan.

4.3. Marshall Islands IDMC data (LOW)

1) All three recorded internal displacement is due to flood events that occurred between 2008 and 2021. Other types of disaster displacement, e.g., displacement due to droughts or heat waves are not recorded.
2) The IDMC disaster displacement risk profile outlines disaster displacement in historical trends of hazard types and associated new displacements. The report highlights the impact of El Niño triggered drought. It further provides two metrics to calculate disaster displacement risk: (i) the modeled estimates on the maximum expected displacement within a certain range of years (Probable Maximum Displacement or PMD) and (ii) the Average Annual Displacement (AAD) to account for long-term displacement trends. The report also contextualizes flood displacement impacts with reports from OCHA that also refer to video footage of the 2014 king tide (OCHA, 2014).
3) Yes, there is anecdotal evidence. However, there are no official displacement statistics. Absenteeism rates for elementary schools in two locations serve as a proxy for displacement to other islands. (IDMC, 2022c). The profile includes qualitative evidence from international organizations such as OCHA as well as damaged houses and affected populations.
4) The data addresses flood-related displacement and is fit for purpose.

5) The data attributes the displacement to the respective flood events but does not give further information about spatio-temporal or demographic features of these disaster displacement events. The level of data granularity is low. In addition, there are only three data points.
6) There are no other data sources available. IOM DTM refers to IDMC data (IOM DTM, 2022b).
7) The IDMC disaster displacement estimates build on EM-DAT disaster data (IDMC, 2022c). A cross-check with EM-DAT is thus not necessary. However, a household questionnaire conducted in 2017 by van der Geest et al. (2020) showed that populations are affected by multiple hazards, including drought, king tides, and storm surges.

4.4. Bangladesh BIHS data (HIGH)

1) BIHS data captured several reasons for the mobility including displacement: employment, education, marriage, health care, medical treatment, violent conflict, extreme weather, and diseases. 71 percent of the people did not provide a reason for displacement and are mapped as uncategorized in the dataset, while 15 % of the participants answered employment as the primary reason for moving. Only four participants out of 5994 interviewees reported being displaced by weather- or climate-related events. However, there is evidence in the literature on the critical role of natural hazards in displacement outcomes in Bangladesh (Gray and Mueller, 2012, IDMC, 2021b, Khan et al., 2021).
2) Yes, BIHS data reports the primary reason for movements at the household level. Several variables contextualize mobility, including employment, education, marriage, health care, escape war or violence, and extreme weather.
3) Yes, Petrova (2021) used BIHS data to understand how floods and droughts drive internal displacement in Bangladesh. This work found that floods and droughts are statistically significant on internal migration due to natural hazards, used as a synonym for disaster displacement, in this data. Gray and Mueller (2012) also suggested a significant correlation between floods and internal displacement in Bangladesh.
4) BIHS data captures internal displacement with the primary reason at the household level. The survey also records flood experiences which can possibly be linked to displacement. Thus, the dataset fits the purpose.
5) The dataset offers high granularity in terms of the timing of displacement (year, month), location (origin, destination), reason, and agency as well as socio-demographic information (age, gender, education).
6) There are other datasets on internal displacement in Bangladesh available: estimates on disaster displacement are provided by IDMC on a yearly level. However, the lack of spatio-temporal variance of IDMC data makes a cross-check for specific extreme weather difficult (IDMC, 2022a). IOM DTM has collected IDP data since 2017 yet misses linkages with disasters.
7) Petrova (2021) developed models for disaster-displacement relationships from the BIHS dataset and statistically evaluated model performance using an Akaike information criterion (AIC) and Bayesian information criterion (BIC), two econometric approaches to assess a statistical model's performance—AIC estimates the maximum likelihood of model fit for evaluation, and BIC shares a similar likelihood function with a different penalty term. Iqbal et al. (2022) used migration data from the Household Income and Expenditure Survey collected by the Bangladesh Bureau of Statistics and compared the results with BIHS survey data for a robustness check.

5. Discussion

Assessing the displacement data revealed grave differences in its quality across existing datasets. We used the flowchart (see Fig. 1) as a starting point to assess scientific standards and the quality of data relevant to weather and disaster displacement. Such evidence is directly usable as a global inventory for the Intergovernmental Panel on Climate Change (IPCC) Working Group II. Overall, our diagnostic tool allows us to advance the transparency of the displacement data landscape in four disaster-prone locations by systematically assessing the evidence of disaster displacement drivers.

Our findings are in line with the literature pinpointing the importance of weather and climate-related events leading to involuntary mobility outcomes, though often mobility decisions are multi-causal and complex (Abel et al., 2019, Black et al., 2013, Hoffmann et al., 2021). The findings further emphasize the need for granular disaggregated displacement and migration data for extreme weather and conflict-affected areas.

We found that not all databases record displacement impacts from weather and climate-related events, e.g., the case of Afghanistan which records conflict as a driver of displacement. Empirical evidence has shown that climate and weather-related events can directly affect conflict, and then indirectly affect displacement via conflict (Abel et al., 2019, Missirian and Schlenker, 2017).

To expand the evidence from available data, there are multiple methodological options. First, displacement reasons could be disentangled by using statistical methods such as causality analyses and pathway models (Ide et al., 2016, Koch et al., 2022, Thalheimer et al., 2023). In Somalia, drought and conflict have led to displacement, though the evidence base of displacement leading to conflict is low (Thalheimer et al., 2023). For example, the PRMN/ UNHCR data could be cross-checked with IDMC displacement or ACLED conflict estimates and EM-DAT disaster records. This is an approach frequently applied in probabilistic event attribution studies (Philip et al., 2020). Furthermore, different types of regression models have been applied to migration and displacement together with weather observations to investigate their causality (Bohnet et al., 2021; Bohra-Mishra et al., 2014; Petrova, 2021).

Second, in the case of low-quality data, we can still bring other types of information to the table. For example, Agent-based Models (ABM) can be useful to model past and future probabilities of disaster displacement flow. Such an approach has been applied by Choquette-Levy et al. (2021) for the agricultural migration in Nepal and by Oh et al. (2022) for water-induced migration in the conceptual environment. If such model estimation is available, low-quality data can be used as a reference point for disaster displacement events, incorporated with other computational and statistical tools, e.g., global sensitivity analysis (Lee et al., 2015).

Third, the use of the medium- and high-quality displacement data has important implications to assess disaster displacement impacts. Disaggregated data by displaced reason, socio-economic, or demographic factors can be used to understand the spatio-temporal network of displacement (Oh et al., 2023, Xiao et al., 2022). Another application of at least medium-quality data is to disentangle reasons for displacement with quantitative approaches, e.g., econometric methods (Abel et al., 2019, Bohra-Mishra et al., 2014, Hsiang, 2016), network modeling (Di Maio et al., 2020, Schon, 2018, Xiao et al., 2022) or agent-based models (Entwisle et al., 2016, Hassani-Mahmooei and Parris, 2012, Kniveton et al., 2011). These approaches can be used to measure displacement responses due to extreme to prepare populations prior to a natural hazard materializing. Such insights can then be used to measure displacement responses and provide intervention points for anticipatory humanitarian action (Thalheimer et al., 2022).

Fourth, highlighting the role of high-quality data, users could apply a reverse engineering approach to tease out variables that are missing in the low- and medium-quality dataset. By asking which variables of the PRMN/ UNHCR dataset one would want to see in other displacement databases, one can define other data sources and input variables ultimately to better understand displacement responses through an integrated data approach.

However, there are several limitations this inventory tool entails. In comparison to existing climate- and disaster-related inventories (Clarke et al., 2021, Otto et al., 2020), our inventory does not touch upon economic impacts and rather seeks to explicitly focus on the practicability of the inventory tool to assess displacement data in the context of weather and climate-related events. We highlight the difficulty of accounting for the complexity of displacement processes, providing evidence for the need of standardized measures and indicators across data providers for displacement data research, analysis, and policy implications. As our goal is to illustrate the tool's usability, we refrain from assessing the quality and consistency from the same providers, rather pointing to the need to cross-check and validate with additional data sources. Though the inventory tool is still limited by geographical biases in both the availability of information and the prevalence of displacement data, it is nevertheless the most complete option we have.

6. Conclusions

Drawing on the framework with seven-step diagnoses, we evaluated the quality of disaster-related displacement data systematically across Somalia, Afghanistan, the Marshall Islands, and Bangladesh. The study's main findings can be summarized as follows: First, the Somalia PRMN/UNHCR dataset evaluation indicates a need for other displacement datasets to strengthen its spatio-temporal granularity including an indication of displacement reasons and triggers.

Monitoring disaster displacement entails accounting for the number of people displaced or homes destroyed in the aftermath of weather and climate-related events. These findings are not just relevant for expanding the disaster displacement evidence but also provide a baseline to inform emergency responses and disaster management for humanitarian actors. Retrospective analysis, however, is only one element of informed planning and decision making, particularly when it comes to mitigation and prevention. It should be complemented with probabilistic analyses and forecasting metrics, such as by the IDMC or the Red Cross/ Red Crescent Climate Center's approach on anticipatory humanitarian action.

Assessing displacement risk in a data-focused way inherently places vulnerability front and center and thus, paves the way for anticipatory humanitarian action on the ground. To ensure its practicability, this inventory approach needs to be evaluated and improved for a variety of stakeholders, including formal feedback and technical development. As a first step, we contribute to the global stocktaking requested by the Paris Agreement and the Sendai Framework on disaster preparedness.

7. Data availability statement

No specific data were created for this manuscript. The data used for the data inventory are open-source and summarized in Table 1. The displacement data for Somalia is available at https://unhcr.github.io/dataviz-somalia-prmn. The conflict-displacement data for Afghanistan is available via IOM-DTM at https://displacement.iom.int/afghanistan and the Multi-Sector Rapid Assessment System at https://afghanresponse.iom.int/. Flood-related displacement estimates in the Marshall Islands are available via IDMC at https://www.internal-displacement.org/countries/marshall-islands. The Bangladesh Integrated Household Survey (BIHS) is available via IFPRI at https://www.ifpri.org/publication/bangladesh-integrated-household-survey-bihs-2011–2012 for 2011–2012, at https://www.ifpri.org/publication/bangladesh-integrated-household-survey-bihs-2015 for 2015, and at https://www.ifpri.org/publication/bangladesh-integrated-household-survey-bihs-2018–2019 for the years 2018–2019.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Abel, G.J., Brottrager, M., Cuaresma, J.C., Muttarak, R., 2019. Climate, conflict and forced migration. Glob. Environ. Chang. 54, 239–249.
Ahmed, A. (2015). *Bangladesh integrated household survey (BIHS) 2011-2012*.
Black, R., Arnell, N.W., Adger, W.N., Thomas, D., Geddes, A., 2013. Migration, immobility and displacement outcomes following extreme events. Environ. Sci. Policy 27, S32–S43. https://doi.org/10.1016/j.envsci.2012.09.001.
Boas, I., Farbotko, C., Adams, H., Sterly, H., Bush, S., van der Geest, K., Wiegel, H., Ashraf, H., Baldwin, A., Bettini, G., Blondin, S., de Bruijn, M., Durand-Delacre, D., Fröhlich, C., Gioli, G., Guaita, L., Hut, E., Jarawura, F.X., Lamers, M., Hulme, M., 2019. Climate migration myths. Nature Clim. Change 9 (12), 901–903. https://doi.org/10.1038/s41558-019-0633-3.
Bohnet, H., Cottier, F., Hug, S., 2021. Conflict versus Disaster-induced Displacement: Similar or Distinct Implications for Security? Civil Wars 23 (4), 493–519. https://doi.org/10.1080/13698249.2021.1963586.
Bohra-Mishra, P., Oppenheimer, M., Hsiang, S.M., 2014. Nonlinear permanent migration response to climatic variations but minimal response to disasters. Proc. Natl. Acad. Sci. 111 (27), 9780–9785. https://doi.org/10.1073/pnas.1317166111.
Cattaneo, C., Beine, M., Fröhlich, C.J., Kniveton, D., Martinez-Zarzoso, I., Mastrorillo, M., Millock, K., Piguet, E., Schraven, B., 2019. Human Migration in the Era of Climate Change. Rev. Environ. Econ. Policy 13 (2), 189–206. https://doi.org/10.1093/reep/rez008.
Choquette-Levy, N., Wildemeersch, M., Oppenheimer, M., Levin, S.A., 2021. Risk transfer policies and climate-induced immobility among smallholder farmers. Nat. Clim. Chang. 11 (12), Article 12. https://doi.org/10.1038/s41558-021-01205-4.
Clarke, B. J., E. L. Otto, F., & Jones, R. G. (2021). Inventories of extreme weather events and impacts: Implications for loss and damage from and adaptation to climate extremes. *Climate Risk Management*, *32*, 100285. Doi: 10.1016/j.crm.2021.100285.
Di Maio, M., Leone Sciabolazza, V., & Molini, V. (2020). *Migration In Libya: A Spatial Network Analysis*. World Bank, Washington, DC. Doi: 10.1596/1813-9450-9110.
Entwisle, B., Williams, N.E., Verdery, A.M., Rindfuss, R.R., Walsh, S.J., Malanson, G.P., Mucha, P.J., Frizzelle, B.G., McDaniel, P.M., Yao, X., Heumann, B.W., Prasartkul, P., Sawangdee, Y., Jampaklay, A., 2016. Climate shocks and migration: An agent-based modeling approach. Popul. Environ. 38 (1), 47–71. https://doi.org/10.1007/s11111-016-0254-y.
FSNAU. (2011). *Food Security and Nutrition Analysis Post Deyr 2010/11,* (Technical Report VI. 36). https://fsnau.org/downloads/FSNAU-Post-Deyr-2010-11-Technical-Report.pdf.
Ginnetti, J., & Franck, T. (2014). *Assessing Drought Displacement Risk for Kenyan. Ethiopian and Somali Pastoralists*. Norwegian Refugee Council & Internal Displacement Monitoring Centre. https://www.internal-displacement.org/sites/default/files/publications/documents/201405-horn-of-africa-technical-report-en.pdf.
Gray, C. L., & Mueller, V. (2012). Natural disasters and population mobility in Bangladesh. *Proceedings of the National Academy of Sciences*, *109*(16), 6000–6005. Doi: 10.1073/pnas.1115944109.
Haritashya, U.K., Bishop, M.P., Shroder, J.F., Bush, A.B.G., Bulley, H.N.N., 2009. Space-based assessment of glacier fluctuations in the Wakhan Pamir, Afghanistan. *Climatic Change* 94 (1), 5–18. https://doi.org/10.1007/s10584-009-9555-9.
Hassani-Mahmooei, B., Parris, B.W., 2012. Climate change and internal migration patterns in Bangladesh: An agent-based model. Environ. Dev. Econ. 17 (6), 763–780. https://doi.org/10.1017/S1355770X12000290.
Hoffmann Pham, K., Luengo-Oroz, M., 2022. Predictive modelling of movements of refugees and internally displaced people: Towards a computational framework. J. Ethn. Migr. Stud. 1–37. https://doi.org/10.1080/1369183X.2022.2100546.
Hoffmann, R., 2022. Contextualizing climate change impacts on human mobility in African drylands. Earth's Future. https://doi.org/10.1029/2021EF002591.
Hoffmann, R., Dimitrova, A., Muttarak, R., Crespo Cuaresma, J., Peisker, J., 2020. A meta-analysis of country-level studies on environmental change and migration. Nat. Clim. Chang. 1–9 https://doi.org/10.1038/s41558-020-0898-6.
Hoffmann, R., Šedová, B., Vinke, K., 2021. Improving the evidence base: A methodological review of the quantitative climate migration literature. Glob. Environ. Chang. 71, 102367 https://doi.org/10.1016/j.gloenvcha.2021.102367.
Holloway, K., Ullah, Z., Ahmadi, D., Hakimi, E., & Ullah, A. (2022). *Climate change, conflict and internal displacement in Afghanistan* (HPG Case Study). ODI. www.odi.org/en/publications/ climate-change-conflict-and-internal-displacement-in-afghanistan-we-are-struggling-to-survive.
Horton, R.M., de Sherbinin, A., Wrathall, D., Oppenheimer, M., 2021. Assessing human habitability and migration. Science 372 (6548), 1279–1283. https://doi.org/10.1126/science.abi8603.
Hsiang, S.M., 2016. Climate Econometrics. 35.
Ide, T., Michael Link, P., Scheffran, J., Schilling, J., 2016. The climate-conflict Nexus: Pathways, regional links, and case studies. In: Handbook on sustainability transition and sustainable peace. Springer, pp. 285–304.
IDMC. (2019). *2019 Global Report on Internal Displacement*. Internal Displacement Monitoring Centre. https://www.internal-displacement.org/sites/default/files/publications/documents/2019-IDMC-GRID.pdf.
IDMC. (2021a). *2021 Global Report on Internal Displacement*. https://www.internal-displacement.org/global-report/grid2021/.
IDMC. (2021b). *Internal Displacement Index 2021 Report*.
IDMC. (2022a). *Country profile Bangladesh*. IDMC. https://www.internal-displacement.org/countries/bangladesh.
IDMC. (2022b). *How we monitor*. IDMC How We Monitor. https://www.internal-displacement.org/monitoring-tools.
IDMC. (2022c). *Sudden-Onset Hazards and the Risk of Future Displacement in the Marshall Islands*. https://www.internal-displacement.org/sites/default/files/publications/documents/220224_IDMC_RiskProfile_TheMarshallIslands.pdf.
IDMC. (2022d). *2022 Global Report on Internal Displacement*. https://www.internal-displacement.org/sites/default/files/publications/documents/IDMC_GRID_2022_LR.pdf.
IDMC. (2023a). *Somalia*. IDMC. https://www.internal-displacement.org/countries/somalia.
IDMC. (2023b, April 22). Global Internal Displacement Database. *IDMC*. https://www.internal-displacement.org/database/displacement-data.
IFPRI. (2021). *Bangladesh Integrated Household Survey (BIHS) 2018-2019* [Data set]. Harvard Dataverse. Doi: 10.7910/DVN/NXKLZJ.
IFRC. (2020). *Forecast-based Financing and disaster displacement: Acting early to reduce the humanitarian impacts of displacement*. https://www.forecast-based-financing.org/wp-content/uploads/2020/10/RCRC_IFRC-FbF-and-Displacement-Issue-Brief.pdf.
IOM. (2022a, July 9). *Sudan—Emergency Event Tracking Report*. https://displacement.iom.int/sites/g/files/tmzbdl1461/files/reports/DTM%20Sudan_%20EET%20Ar%20Rahad%2C%20Al%20Mafaza%2C%20and%20Al%20Qureisha%2C%20Gedaref%20%28Update%20001%29.pdf.
IOM. (2022b, September). *IOM DTM*. https://displacement.iom.int/.
IOM. (2022a). *Environmental Migration*. Migration Data Portal. https://www.migrationdataportal.org/themes/environmental_migration_and_statistics.
IOM. (2022b). *Methodological framework for quantifying displacement and mobility in Displacement Tracking Matrix (DTM) operations*. International Organization for Migration. https://dtm.iom.int/sites/g/files/tmzbdl1461/files/DTM%20Methodological%20Framework%20-%202nd%20Edition%202022_0.pdf.
IOM. (2023). *Multi-Sector Rapid Assessment System*. https://afghanresponse.iom.int/Dashboard/Download.aspx.
IOM DTM. (2018). *Displacement Tracking Matrix—Infosheet*. https://displacement.iom.int/system/tdf/DOE%20Infosheet%20-%20DTM%20v12.0_20180308.pdf?file=1&type=node&id=1205.
IOM DTM. (2022a). *Afghanistan | Displacement*. https://displacement.iom.int/afghanistan.
IOM DTM. (2022b). *Marshall Islands | Displacement*. https://displacement.iom.int/marshall-islands.
IOM & IDMC. (2022). *Displacement indicators for DRR*. https://environmentalmigration.iom.int/sites/g/files/tmzbdl1411/files/documents/Displacement%20indicators%20for%20DRR%20State%20of%20the%20art%20report.pdf.

Iqbal, K., Pabon, M.N.F., Hoque, M.R., Shashi, N.A., 2022. Local Nonfarm Opportunities and Migration Decisions: Evidence from Bangladesh. SSRN Electron. J. https://doi.org/10.2139/ssrn.4165708.

Islam, A.H.M.S., von Braun, J., Thorne-Lyman, A.L., Ahmed, A.U., 2018. Farm diversification and food and nutrition security in Bangladesh: Empirical evidence from nationally representative household panel data. Food Security 10 (3), 701–720. https://doi.org/10.1007/s12571-018-0806-3.

Kalin, W., 2008. Guiding principles on internal displacement. Stud. Transnat'l Legal Pol'y 38, 1.

Kam, P.M., Aznar-Siguan, G., Schewe, J., Milano, L., Ginnetti, J., Willner, S., McCaughey, J.W., Bresch, D.N., 2021. Global warming and population change both heighten future risk of human displacement due to river floods. Environ. Res. Lett. 16 (4), 044026 https://doi.org/10.1088/1748-9326/abd26c.

Khan, M.R., Huq, S., Risha, A.N., Alam, S.S., 2021. High-density population and displacement in Bangladesh. Science 372 (6548), 1290–1293. https://doi.org/10.1126/science.abi6364.

Kniveton, D., Smith, C., Wood, S., 2011. Agent-based model simulations of future changes in migration flows for Burkina Faso. Glob. Environ. Chang. 21, S34–S40. https://doi.org/10.1016/j.gloenvcha.2011.09.006.

Koch, N., Naumann, L., Pretis, F., Ritter, N., Schwarz, M., 2022. Attributing agnostically detected large reductions in road CO2 emissions to policy mixes. Nat. Energy 1–10. https://doi.org/10.1038/s41560-022-01095-6.

Lee, J.-S., Filatova, T., Ligmann-Zielinska, A., Hassani-Mahmooei, B., Stonedahl, F., Lorscheid, I., Voinov, A., Polhill, J.G., Sun, Z., Parker, D.C., 2015. The complexities of agent-based modeling output analysis. J. Artif. Soc. Soc. Simul. 18 (4).

Mallick, B., Ahmed, B., Vogt, J., 2017. Living with the Risks of Cyclone Disasters in the South-Western Coastal Region of Bangladesh. Environments 4 (1). https://doi.org/10.3390/environments4010013.

Mastrandrea, M. D., Field, C. B., Stocker, T. F., Edenhofer, O., Ebi, K. L., Frame, D. J., Held, H., Kriegler, E., Mach, K. J., & Matschoss, P. R. (2010). *Guidance note for lead authors of the IPCC fifth assessment report on consistent treatment of uncertainties*.

Maystadt, J.-F., Ecker, O., 2014. Extreme Weather and Civil War: Does Drought Fuel Conflict in Somalia through Livestock Price Shocks? Am. J. Agric. Econ. 96 (4), 1157–1182. https://doi.org/10.1093/ajae/aau010.

McLeman, R., Wrathall, D., Gilmore, E., Thornton, P., Adams, H., Gemenne, F., 2021. Conceptual framing to link climate risk assessments and climate-migration scholarship. Clim. Change 165 (1), 24. https://doi.org/10.1007/s10584-021-03056-6.

Missirian, A., Schlenker, W., 2017. Asylum applications respond to temperature fluctuations. Science 358 (6370), 1610–1614. https://doi.org/10.1126/science.aao0432.

NASA. (2020, August 1). *Intense Flooding in Bangladesh* [Text.Article]. NASA Visible Earth. https://visibleearth.nasa.gov/images/147057/intense-flooding-in-bangladesh/147057t.

OCHA. (2014). *Flash Update—Marshall Islands | King Tides, 4 March 2014*. https://reliefweb.int/report/marshall-islands/ocha-flash-update-marshall-islands-king-tides-4-march-2014.

OCHA. (2021). *Somalia: Drought Situation Report No.1 (As of 23 November 2021) - Somalia | ReliefWeb*. https://reliefweb.int/report/somalia/somalia-drought-situation-report-no1-23-november-2021.

OCHA. (2023). *IDPs Tracking | HumanitarianResponse*. Humanitarian Response. https://www.humanitarianresponse.info/en/operations/stima/idps-tracking.

Oh, W., Carmona-Cabrero, A., Muñoz-Carpena, R., Muneepeerakul, R., 2022. On the Interplay Among Multiple Factors: Effects of Factor Configuration in a Proof-of-Concept Migration Agent-Based Model. J. Artif. Soc. Soc. Simul. 25 (2), 7. https://doi.org/10.18564/jasss.4793.

Oh, W., Muneepeerakul, R., Rubenstein, D. I., & Levin, S. (2023). *Emergent Network Patterns of Internal Displacement in Somalia Driven by Natural Disasters and Conflicts* (SSRN Scholarly Paper No. 4340566). Doi: 10.2139/ssrn.4340566.

Otto, F.E.L., Harrington, L.J., Frame, D., Boyd, E., Lauta, K.C., Wehner, M., Clarke, B., Raju, E., Boda, C., Hauser, M., James, R.A., Jones, R.G., 2020. Towards an inventory of the impacts of human-induced climate change. Bull. Am. Meteorol. Soc. 1–17 https://doi.org/10.1175/BAMS-D-20-0027.1.

Petrova, K., 2021. Natural hazards, internal migration and protests in Bangladesh. J. Peace Res. 58 (1), 33–49. https://doi.org/10.1177/0022343320973741.

Philip, S., Kew, S.F., van Oldenborgh, G.J., Otto, F.E.L., Vautard, R., van der Wiel, K., King, A., Lott, F., Arrighi, J., Singh, R., van Aalst, M., 2020. A protocol for probabilistic extreme event attribution analyses. Adv. Stat. Climatol. Meteorol. Oceanogr. 6 (2), 177–203. https://doi.org/10.5194/ascmo-6-177-2020.

Pörtner, H. O., Roberts, D. C., Adams, H., Adler, C., Aldunce, P., Ali, E., Begum, R. A., Betts, R., Kerr, R. B., & Biesbroek, R. (2022). *IPCC, 2022: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (p. 3056 pp.).

Přívara, A., & Přívarová, M. (2019). Nexus between Climate Change, Displacement and Conflict: Afghanistan Case. *Sustainability*, *11*(20), Article 20. Doi: 10.3390/su11205586.

Qutbudin, I., Shiru, M.S., Sharafati, A., Ahmed, K., Al-Ansari, N., Yaseen, Z.M., Shahid, S., Wang, X., 2019. Seasonal Drought Pattern Changes Due to Climate Variability: Case Study in Afghanistan. Water 11 (5), Article 5. https://doi.org/10.3390/w11051096.

Raleigh, C., Linke, A., Hegre, H., Karlsen, J., 2010. Introducing ACLED: An Armed Conflict Location and Event Dataset: Special Data Feature. J. Peace Res. 47 (5), 651–660. https://doi.org/10.1177/0022343310378914.

Ranghieri, F., Fallesen, D.M.G., Jongman, B., Balog-Way, S.A.B., Mashahid, S.S., Siercke, G.A., Simpson, A.L., 2017. Disaster risk profile: Afghanistan. The World Bank.

Schon, J., 2018. Using ERGMs to Disaggregate Displacement Cascades *. J. Soc. Struct. 19 (1), 1–40. https://doi.org/10.21307/joss-2018-006.

Sedova, B., Kalkuhl, M., 2020. Who are the climate migrants and where do they go? Evidence from rural India. *World Development* 129, 104848. https://doi.org/10.1016/j.worlddev.2019.104848.

Sununtnasuk, C., Fiedler, J.L., 2017. Can household-based food consumption surveys be used to make inferences about nutrient intakes and inadequacies? A Bangladesh case study. Food Policy 72, 121–131. https://doi.org/10.1016/j.foodpol.2017.08.018.

Tai, X.H., Mehra, S., Blumenstock, J.E., 2022. Mobile phone data reveal the effects of violence on internal displacement in Afghanistan. Nature Human Behaviour 6 (5), Article 5. https://doi.org/10.1038/s41562-022-01336-4.

Task Force on Displacement. (2018). Systematic data collection and monitoring of displacement and its impacts at local, national, regional and international level to inform comprehensive needs and risk assessments for the formulation of policy and plans. https://unfccc.int/sites/default/files/resource/WIM%20TFD%20III.1-3%20Output.pdf.

Thalheimer, L. (2022). Compound impacts of extreme weather events and Covid-19 on climate mobilities. *Area*, *n/a*(n/a). Doi: 10.1111/area.12821.

Thalheimer, L., Schwarz, M.P., Pretis, F., 2023. Large weather and conflict effects on internal displacement in Somalia with little evidence of feedback onto conflict. Glob. Environ. Chang. 79, 102641 https://doi.org/10.1016/j.gloenvcha.2023.102641.

Thalheimer, L., Simperingham, E., Jjemba, E.W., 2022. The role of anticipatory humanitarian action to reduce disaster displacement. Environ. Res. Lett. 17 (1), 014043 https://doi.org/10.1088/1748-9326/ac4292.

Thalheimer, L., Williams, D.S., van der Geest, K., Otto, F.E.L., 2021. Advancing the Evidence Base of Future Warming Impacts on Human Mobility in African Drylands. Earth's Future 9 (10). https://doi.org/10.1029/2020EF001958.

UNHCR. (2021). *Global Report 2021*. https://reporting.unhcr.org/globalreport2021/pdf.

UNHCR. (2022a). *Situation Horn of Africa Somalia Situation*. https://data2.unhcr.org/en/situations/horn.

UNHCR. (2022b). *UNHCR Somalia—Interactive Internal Displacements Visualisation*. UNHCR Somalia Internal Displacement. https://unhcr.github.io/dataviz-somalia-prmn/index.html.

UNHCR. (2023). *UNHCR - Refugee Statistics*. UNHCR. https://www.unhcr.org/refugee-statistics/.

UNHCR Somalia. (2017). *Protection & Return Monitoring Network (PRMN)—Notes on methodology*. https://data2.unhcr.org/en/documents/details/53888.

van der Geest, K., Burkett, M., Fitzpatrick, J., Stege, M., Wheeler, B., 2020. Climate change, ecosystem services and migration in the Marshall Islands: Are they related? Clim. Change 161 (1), 109–127. https://doi.org/10.1007/s10584-019-02648-7.

Walton, D., Arrighi, J., van Aalst, M., & Claudet, M. (2021). *The compound impact of extreme weather events and COVID-19*. 34.

Xiao, T., Oppenheimer, M., He, X., Mastrorillo, M., 2022. Complex climate and network effects on internal migration in South Africa revealed by a network model. Popul. Environ. 43 (3), 289–318. https://doi.org/10.1007/s11111-021-00392-8.