ICPAC

Final Report

Development of a data model and capacity development for human mobility due to slow-onset events in the IGAD Region

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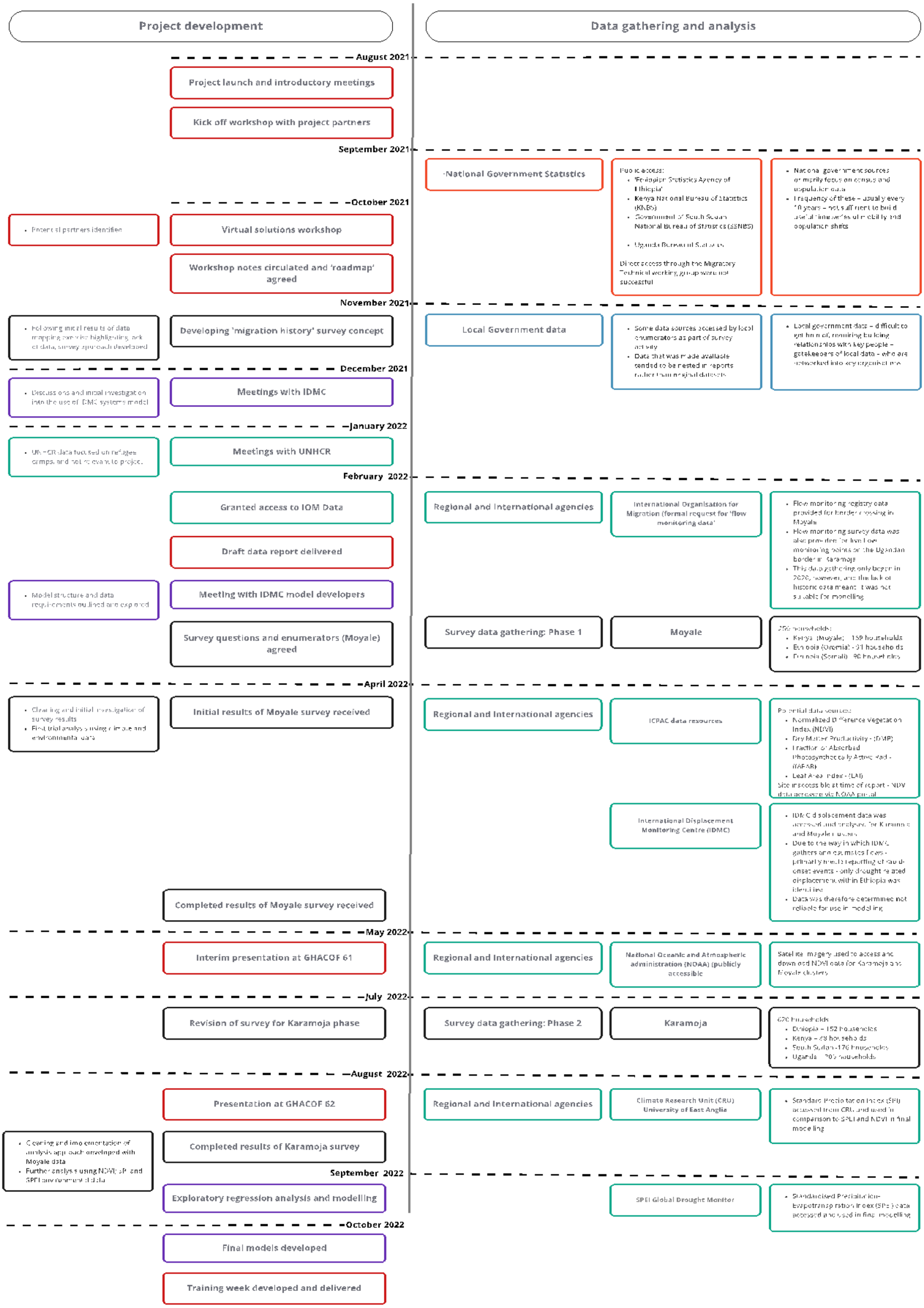
Project Timeline



1. Overview of topic: climate change and mobility

1.1 Different types of human mobility

Human mobility can be categorized in a variety of ways. For example, mobility flows can be separated in terms of the distance of the movement, the length of time spent moving, the reasons for the movement, or by the outcome of the mobility. People may be displaced, meaning, they have little choice but to move, or they may choose to move. They may be prevented from moving despite wanting to: often referred to as trapped populations. Migrants can move seasonally, temporarily, or permanently. Their decisions to move might be influenced by social and kin relationships, or by the desire to avoid persecution or conflict or for perceived better and/or more secure lives or livelihoods[1]. Figure 1 presents some of the key spectra of categories and dimensions of human mobility. The decision to migrate, the processes of migration and the outcomes of migration are influenced by macro, meso and micro factors and contexts[1,2]. Different labels might be applied to people on the move, by the governments of the origin and destination countries, or by those moving themselves[3].

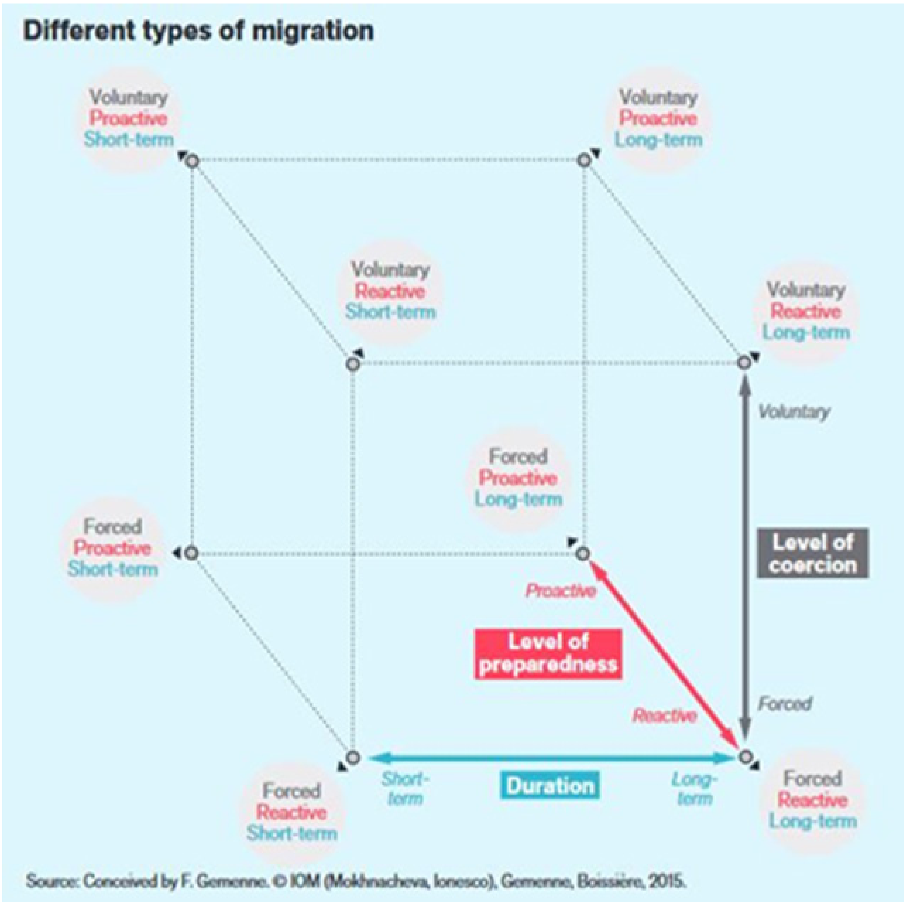


Figure 1. Key spectra of categories and dimensions of human mobility

[1] Black, R., Bennett, S.R., Thomas, S.M. and Beddington, J.R., 2011. Migration as adaptation. Nature, 478(7370), pp.447-449.
[2] Hunter, L.M., 2005. Migration and environmental hazards. Population and environment, 26(4), pp.273-302.
[3] Piguet, E., 2013. From "primitive migration" to "climate refugees": The curious fate of the natural environment in migration studies. Annals of the Association of American Geographers, 103(1), pp.148-162.

For the sake of this assessment, we follow the International Organisation of Migration's[4] definitions as follows:

(1) Migration: The movement of persons away from their place of usual residence, either across an international border or within a State.

(2) Displacement: The movement of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular, as a result of or in order to avoid the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters.[5] Note: Unlike the Guiding Principles on Internal Displacement, the above definition is meant to cover both internal and cross-border displacement. Principle 6 of the Guiding Principles stipulates the right to be protected against arbitrary displacement. Displacement is considered arbitrary in the following circumstances: "(a) When it is based on policies of apartheid, "ethnic cleansing" or similar practices aimed at/or resulting in altering the ethnic, religious or racial composition of the affected population; (b) In situations of armed conflict, unless the security of the civilians involved or imperative military reasons so demand; (c) In cases of large-scale development projects, which are not justified by compelling and overriding public interests; (d) In cases of disasters, unless the safety and health of those affected requires their evacuation; and (e) When it is used as a collective punishment".[6] In international humanitarian law, the (forced) displacement of civilians is prohibited and constitutes a war crime both in times of international and non-international armed conflicts except when required for their security or imperative military reasons.[7]

(3) Refugee: A person who, owing to a well-founded fear of persecution for reasons of race, religion, nationality, membership of a particular social group or political opinion, is outside the country of his nationality and is unable or, owing to such fear, is unwilling to avail himself of the protection of that country; or who, not having a nationality and being outside the country of his former habitual residence as a result of such events, is unable or, owing to such fear, is unwilling to return to it.[8] Note: Under international refugee law, recognition as a refugee is declaratory and not constitutive. "A person is a refugee within the meaning of the 1951 Convention as soon as he fulfils the criteria contained in the definition. This would necessarily occur prior to the time at which his refugee status is formally determined. Recognition of his refugee status does not therefore make him a refugee but declares him to be one. He does not become a refugee because of recognition, but is recognized because he is a refugee"[9]. The second part of the definition also covers stateless persons who are

[4] IOM, 2019. Glossary on Migration. https://publications.iom.int/books/international-migration-law-ndeg34-glossary-migration

[5] Adapted from Guiding Principles on Internal Displacement, annexed to United Nations Commission on Human Rights, Report of the Representative of the Secretary-General, Mr Francis M. Deng, Submitted Pursuant to Commission Resolution 1997/39, Addendum (11 February 1998) UN Doc. E/CN.4/1998/53/Add.2, para. 2 of the introduction.

[6] Guiding Principles on Internal Displacement, annexed to United Nations Commission on Human Rights, Report of the Representative of the Secretary General, Mr Francis M. Deng, Submitted Pursuant to Commission Resolution 1997/39, Addendum (11 February 1998) UN Doc. E/ CN.4/1998/53/Add.2, Principle 6.2). In order not to be arbitrary, displacement shall also last no longer than required by the circumstances (ibid., Principle 6.3).

[7] Geneva Convention (IV) relative to the Protection of Civilian Persons in Time of War (adopted 12 August 1949, entered into force 21 October 1950) 75 UNTS 287, Art. 49(1); Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of Non-International Armed Conflicts (adopted 8 June 1977, entered into force 7 December 1978) 1125 UNTS 609 (Additional Protocol II) Art. 17(1) and (2); Rome Statute of the International Criminal Court (adopted 17 July 1998, entered into force 1 July 2002) 2187 UNTS 3, Art. 8(2)(a)(viii) and (e)(viii)). The prohibition of individual or mass displacement is also endorsed by the African Union Convention for the Protection and Assistance of Internally Displaced Persons in Africa (Kampala Convention) (adopted 23 October 2009, entered into force 6 December 2012) Art. 4(4)(b))

[8] Adapted from Convention relating to the Status of Refugees ((adopted 28 July 1951, entered into force 22 April 1954) 189 UNTS 137) Art. 1A(2).

[9] United Nations High Commissioner for Refugees, Handbook and Guidelines on Procedures and Criteria for Determining Refugee Status (2011) HCR/1P/4/enG/Rev. 3, para. 9).

outside their country of habitual residence. Instruments adopted at the regional level complement the Convention relating to the Status of Refugees ((adopted 28 July 1951, entered into force 22 April 1954) 189 UNTS 137) and build upon its definition, by including specific reference to a number of objective circumstances which may compel a person to leave their country. Article 1(2) of the Convention Governing Specific Aspects of Refugee Problems in Africa ((adopted 10 September 1969, entered into force 20 June 1974) 1001 UNTS 45) includes in the definition of refugees also any person compelled to leave his or her country "owing to external aggression, occupation, foreign domination or events seriously disturbing public order in either part or the whole of his country or origin or nationality". Similarly, the 1984 Cartagena Declaration states that refugees also include persons who flee their country "because their lives, security or freedom have been threatened by generalised violence, foreign aggression, internal conflicts, massive violations of human rights or other circumstances which have seriously disturbed public order".

(4) Relocation: In the context of humanitarian emergencies, relocations are to be considered as internal humanitarian evacuations and are understood as large-scale movements of civilians, who face an immediate threat to life in a conflict setting, to locations within the same country where they can be more effectively protected.[10] Note: Relocation is also among the guarantees laid down in the Guiding Principle on Internal Displacement in case of displacement occurring in situations other than during the emergency stages of armed conflicts and disasters. [11] These guarantees also provide that "the authorities concerned shall endeavour to involve those ffected, particularly women, in the planning and management of their relocation" (ibid., Principle 7(3)(d)).

(5) Resettlement (refugees): The transfer of refugees from the country in which they have sought protection to another State that has agreed to admit them – as refugees – with permanent residence status. [12] Note: Resettled refugees will usually be granted asylum or some other form of long-term resident rights and, in many cases, will have the opportunity to be naturalized.

(6) Trapped populations: Populations who do not migrate, yet are situated in areas under threat, [...] at risk of becoming 'trapped' or having to stay behind, where they will be more vulnerable to environmental shocks and impoverishment. [13] Note: This notion of trapped populations applies in particular to poorer households who may not have the resources to move and whose livelihoods are affected. [14]

1.2 Climate change and its impacts

The idea of people moving due to changes and variabilities in the environment first came to precedence in the 1980s with the publications of Hinnawi in 1985 and Jacobson in 1988. These publications floated the idea that hundreds of millions of people could be on the move by the

[10] Adapted from International Organization for Migration, IOM Key Principles for Internal Humanitarian Evacuations/Relocations of Civilian Populations in Armed Conflict (undated) www.iom.int/sites/default/files/Int.%20humanitarian-%20Relocations-%20 key%20principles%20IOMFIN.pdf (last accessed 8 February 2018) (definition adapted from Global Protection Cluster Working Group, Handbook for the Internally Displaced People (2010)).

[11] Guiding Principles on Internal Displacement, annexed to United Nations Commission on Human Rights, Report of the Representative of the Secretary-General, Mr Francis M. Deng, Submitted Pursuant to Commission Resolution 1997/39, Addendum (11 February 1998) UN Doc. E/CN.4/1998/53/ Add.2, Principle 7(3)(b)

[12] Adapted from United Nations High Commissioner for Refugees, UNHCR Resettlement Handbook (2011) p. 3.

[13] Adapted from Foresight, Migration and Global Environmental Change (2011) p. 25, cited in International Organization for Migration, Migration, Environment and Climate Change: Evidence for Policy (MECLEP), Glossary (2014) p. 17.

[14] International Organization for Migration, Migration, Environment and Climate Change: Evidence for Policy (MECLEP), Glossary (2014) p. 17

middle of this century because of environmental stresses and shocks to lives and livelihoods. These publications referred to these populations as 'environmental migrants' and 'environmental refugees'[15].

Since the 1980s there has been a growing recognition in policy circles that the movement of people in terms of environmental change might be even more extreme when considering anthropogenically induced climate change. Often in discussions around migration in the context of climate variability and change, migrants are separated into those that move in response to 'rapid changes' in the climate, such as floods, storms, hurricanes and tropical cyclones and those people that move because of more gradual perturbations, referred to as 'slow onset changes' such as drought and sea level rise. While of course this separation is not mutually exclusive with people subject to both slow onset and rapid changes this distinction remains a common way to separate different types of migrants in the context of climate variability and change. Migration is also often categorized in terms of its' drivers or determinants such as economic migration or migration for education. While undoubtedly there are sometimes individual drivers of migration, more often the causes of mobility are multiple and interlinked. Thus, one can imagine that the impacts of climate change may reduce the viability of agricultural livelihoods in one location with changing rainfall patterns and increased temperatures, thus forcing people to move (i.e. they become displaced) but at the same time increasing the draw of a particular new destination by a new job opportunity. Whether the pull factor is climate related or not this raises the concept that someone may simultaneously be displaced from a location but also choose to move to another location. This conception is probably best captured by the relatively old 'theory' used to explain mobility known as the Push and Pull Theory or Lee' Theory after its author Everett Spurgeon Lee in 1966. This theory involves push factors associated with the area of origin migration including political instability and conflict, a lack of economic/livelihood opportunities, and a lack of access to resources; 'pull' factors such as employment opportunities, demand for workers and higher wages in destination regions; intervening obstacles such distance to travel, transport and borders; and personal factors such as the capacity to move and cultural, social and spiritual attachments to a place. Other prominent 'theories' of migration relevant to a context of climate change include those of Massey in 2015[16] who highlighted the importance of social networks in facilitating migration and the New Economics of Labour Migration by Stark and Bloom[17] in 1985 that positions migration as a means of household income diversification and risk reduction.

1.3 The Foresight model

The acknowledgement that people at the risk of the impacts of climate and environmentally variability and change may not only move in response to the actual impacts of the associated hazards but also proactively as a form of risk reduction and adaptive capacity building was particularly cemented by the UK's Government Office for Science funded Foresight project on Migration and Global Environmental Change. The project report received extensive media coverage and is widely acknowledged in the scientific and practitioner fields related to environment and migration. While

[15] However, it should be noted that currently people moving as the result of variability and changes in the environment (or the climate) are not covered by the United Nations Refugee Act.

[16] Massey, D.S., 2015. A missing element in migration theories. Migration letters: an international journal of migration studies, 12(3), p.279.

[17] Stark, O. and Bloom, D.E., 1985. The new economics of labor migration. The american Economic review, 75(2), pp.173-178.

not immune from criticism (see Bettini 2014[18] and Felli and Castree 2012[19]) the central conception of understanding the nexus between the environment and climate and mobility is still often referred to in studies of the subject. Figure 2 shows this conception.

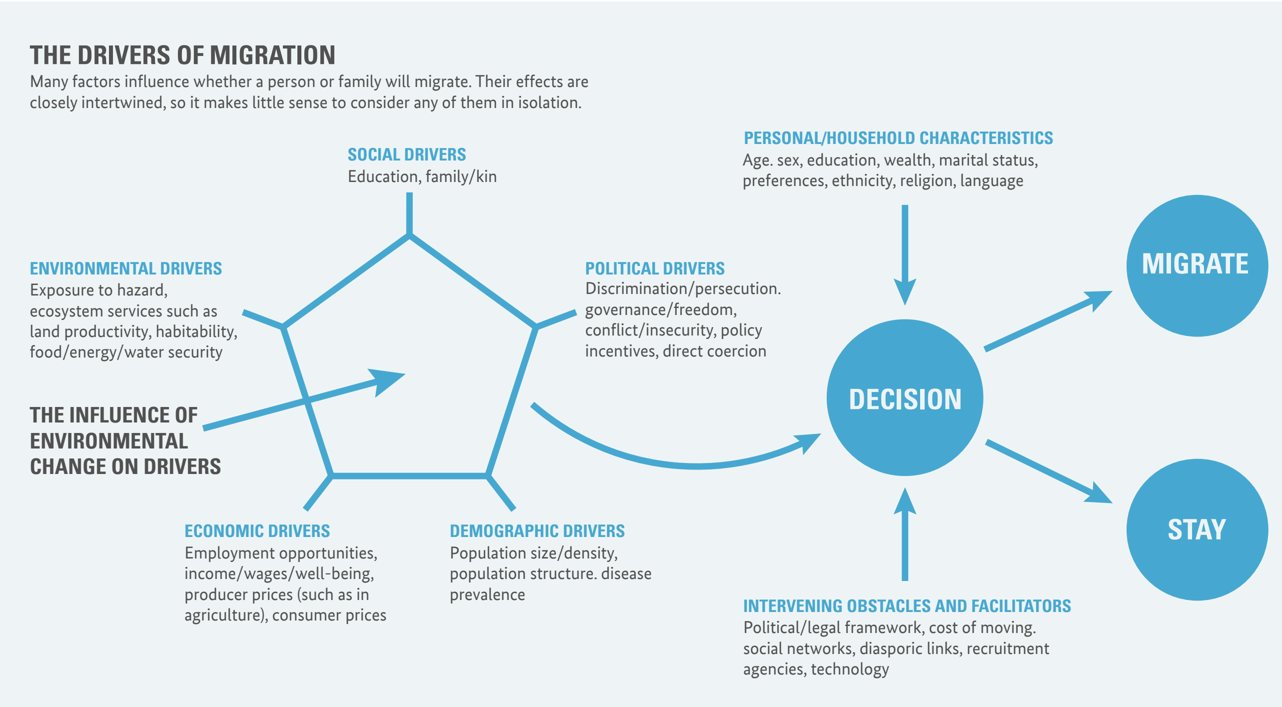


Figure 2. The Foresight conception of the environment and migration nexus (Black et al. 2011)[1]

Moving from left to right the Foresight conception sees migration determined by macro drivers (social, political, economic, environment and demographic), and subject to meso factors such as the obstacles and facilitators of political/legal frameworks, the cost of moving, social networks, diasporic links, recruitment agencies and technology and micro factors of personal and household characteristics of age, sex, education, wealth, marital status, preferences, ethnicity religion and language. Here the influence of climate variability and change is depicted as occurring through the meso drivers of migration although obviously it can also be imagined that the impacts of climate are felt both on personal and household characteristics and the intervening obstacles and facilitators with changes in policies in response to climate change. In this conception the decision to migrate is characterized as a simple binary choice between moving or staying, where migrating includes both forced movement such as displacement or relocation and migration by choice. Likewise, the decision to stay includes both those who choose to stay and those that are trapped (see definitions above) by the impacts of climate variability and change. The Foresight report highlighted that in the context of climate variability and change people are as likely to migrate into places of environmental vulnerability as away from them citing the example of Dakar in Senegal where 40% of those who moved there between 1998 and 2008 live in areas of high flood risk[20]. It also noted that other non-climatically related factors of political instability, poor governance, conflict and social pressures can compound the influence of climate variability and change on mobility.

[19] Felli, R. and Castree, N., 2012. Neoliberalising adaptation to environmental change: foresight or foreclosure?. Environment and Planning A, 44(1), pp.1-4.
[20] World Bank World Development Report 2010: Development and Climate Change (World Bank, 2010).

1.4 Key findings on climate impacts and migration in the literature

In the last decade there has been an explosion of studies looking at the link between the nexus between climate and migration. Most of these studies use the analogy of the relationship between past climate variability and mobility to explore how climate change might influence movements. Using the categorization of these studies into slow and rapid onset changes the following findings are as follows (from Cattaneo et al 2019[21]):

- In most cases, displacements in response to rapid onset events such as floods and cyclones tend to be temporary and over short distances [22].
- The repetition of different rapid onsets over a short period of time [23,24] can impact mobility very differently compared to a single disaster, regardless of their intensity [25].
- Cases of mass movement of people (predominantly internal displacement) in response to drought have been reported in Africa (Sahel, Ethiopia), South America (Argentina, Brazil), the Middle East (Syria, Iran), Central Asia, and Southern Asia [26,27]. There has been a number of criticisms of these studies. These criticisms focus on the observation that the migration numbers are small relative to the numbers of people affected by drought, and that climatic push events are just one of many factors influencing migration decisions [28,1,29].
- In other contexts, drought can result in a reduction in migration. For example, during the mid-1980s drought in Mali [30] found that there was a reduction in international migration due to a lack of available resources to finance the migration journey. Supporting this finding, Cattaneo and Peri (2016) [31] showed that a gradual increase in temperatures reduces international migration from poor countries. Meanwhile, Gro¨schl and Steinwachs (2017) [32] showed that drought increases migration, but only for middle-income countries, which are neither rich enough to have insurance schemes nor poor enough to lack resources to migrate, suggesting that liquidity constraints play an important role in the relationship between climate change and migration.

[21] Cattaneo, C., Beine, M., Fröhlich, C.J., Kniveton, D., Martinez-Zarzoso, I., Mastrorillo, M., Millock, K., Piguet, E. and Schraven, B., 2019. Human migration in the era of climate change. Review of Environmental Economics and Policy.
[22] McLeman, R. and Gemenne, F. eds., 2018. Routledge handbook of environmental displacement and migration. London/New York: Routledge.
[23] Devkota, R.P., Pandey, V.P., Bhattarai, U., Shrestha, H., Adhikari, S. and Dulal, K.N., 2017. Climate change and adaptation strategies in Budhi Gandaki River Basin, Nepal: a perception-based analysis. Climatic Change, 140(2), pp.195-208.
[24] Kim, H., and D. W. Marcouiller. 2017. Mitigating flood risk and enhancing community resilience to natural disasters: plan quality matters. Environmental Hazards 17:397–417.
[25] Berlemann, M., and M. F. Steinhardt. 2017. Climate change, natural disasters, and migration—a survey of the empirical evidence. CESifo Economic Studies 19:353–85.
[26] Miyan, M. A. 2015. Droughts in Asian least developed countries: vulnerability and sustainability. Weather and Climate Extremes 7:8–23.
[27] Piguet, E., and F. Laczko. 2014. People on the move in a changing climate. The regional impact of environmental change on migration. Dordrecht: Springer.
[28] Smith, K. 2001. Environmental hazards, assessing the risk and reducing disaster. London: Routledge.
[29] Martin, M., M. Billah, T. Siddiqui, C. Abrar, R. Black, and D. Kniveton. 2014. Climate-related migration in rural Bangladesh: a behavioural model. Population and Environment 36:85–110.
[30] Findley, S.E., 1994. Does drought increase migration? A study of migration from rural Mali during the 1983–1985 drought. International migration review, 28(3), pp.539-553.
[31] Cattaneo, C., and G. Peri. 2016. The migration response to increasing temperatures. Journal of Development Economics 122:127–46.
[32] Gröschl, J., and T. Steinwachs. 2017. Do natural hazards cause international migration? CESifo Economic Studies 63:445–80

- The impact of the climate on migration differs according to factors such as wealth, the level of financial and human capital, gender, age, health, the availability of places to move to, and the capacity to track what happens to property and assets left behind. In terms of the influence of wealth some studies have been shown that low-income families are more likely to move in response to climatic events [33,34,35,36]. Yet other studies have found the opposite effect with liquidity constraints preventing migration [37,21,38]. One explanation of this apparent discrepancy is that the migration takes different forms. For example, poor families may respond to negative climatic shocks through "survival" migration—i.e., temporary moves over short distances[27]. In contrast, wealthier families tend to engage in "profitable investment" migration, which involves urban moves, longer-distance migration, or even international migration, and spans a longer period of time. Kleemans (2015)[27] estimates that migration to distant and international destinations is about four times as costly as survival migration and is thus cost prohibitive for poor people. Moreover, she finds that survival and profitable investment migration are substitutes, which means that families migrating a short distance to cope with a negative shock are less likely to invest in long-distance migration."[39]

[33] Jayachandran, S. 2006. Selling labor low: wage responses to productivity shocks in developing countries. Journal of Political Economy 114:538–75.

[34] Gray, C. L., and V. Mueller. 2012. Natural disasters and population mobility in Bangladesh. Proceedings of the National Academy of Sciences of the United States of America 109:6000–6005.

[35] Mueller, V., C. Gray, and K. Kosec. 2014. Heat stress increases long-term human migration in rural Pakistan. Nature Climate Change 4:182–85.

[36] Mastrorillo, M., R. Licker, P. Bohra-Mishra, G. Fagiolo, L. D. Estes, and M. Oppenheimer. 2016. The influence of climate variability on internal migration flows in South Africa. Global Environmental Change 39:155–69.

[37] Kleemans, M. 2015. Migration choice under risk and liquidity constraints. Paper presented at the Agricultural and Applied Economics Association and Western Agricultural Economics Association Joint Annual Meeting, July 26–28, San Francisco, CA.

[38] Bazzi, S. 2017. Wealth heterogeneity and the income elasticity of migration. American Economic Journal: Applied Economics 9:219–55.

2. Data on climate change and mobility

2.1 Overview of different data formats

The role of data is to explore and establish the causal links between human-mobility and the changing climate. Much of our insight into the potential impact of climate change and variability on migration is drawn from empirical studies that analyze population responses to past environmental shocks and stressors, which are assumed to be analogous to the future impacts of climate change and variability [40,41]. The challenge is, however, to identify the specific influences and interactions between environmental and non-environmental factors.

There are numerous potential sources of data that can be potentially drawn on to provide information and insight into the historic impact of climate and environmental shocks and stressors. As such, data sources can be categorized by the information that they will provide:

(1) Human mobility

- Mobility – migration and displacement
- Population distribution and density
- Demographics, and demographic change

(2) Climate and environmental

- Climate conditions, such as rainfall and temperature records
- Environmental data, including Aridity, Land degradation, Agricultural impact data, e.g., livestock and crop yields

(3) Other variables and drivers of mobility, for example

- Conflict
- Disease
- Local market prices – as traders and consumers

Potential sources of such data can be divided into macro-level (grid-cell) data and micro-level data. Macro level data records the typically includes a large number of data points at an aggregate level. This can help identify the direction and magnitude of potential drivers, but does not provide in-depth perspective on mechanisms and granularity to deduce the specific causalities.

[21] 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. Review of Environmental Economics and Policy, 13(2), 189–206. https://doi.org/10.1093/reep/rez008

[22] Lincke, D., & Hinkel, J. (2021). Coastal Migration due to 21st Century Sea-Level Rise. Earth's Future, 9(5), e2020EF001965. https://doi.org/10.1029/2020EF001965

Micro or survey data are data on individual population units, and therefore will include a small number of data points. These data are ordinarily drawn from surveys reflecting local knowledge and experiences. As such, there is a limit to how far the results of data analysis can be generalized to other contexts, and whether they will cover the time periods necessary to inform modelling.

The following is an outline of the potential sources of such data:

(1) Macro-Level Data

Population Density

- **WorldPOP**
  - Utilises non-spatial population data – for example, tabular counts of population listed by administrative area - and spatially explicit administrative boundary data, which is analysed through a variety of approaches in order to assign estimated population counts to grid cells

- **Gridded Population of the World (GPW)**
  - Models the distribution of human population (counts and densities) on a continuous global raster surface, and is available from NASA Socioeconomic Data and Applications Center (SEDAC)

Human settlements

- **Global Human Settlement Layer (GHSL)**
  - Contains more than 12.4k billion of individual image data records collected by different satellite sensors in the past 40 years are classified and automatically selected if they correspond to a built-up structure. The density of buildings per unit surface is determined by machine learning - automatically analysing the image data on a gradation from darker (no buildings recognized) to brighter (spatial units full of buildings – or high density of buildings). Available from NASA Socioeconomic Data and Applications Center.

Census data

- **IPUMS International**
  - Primary data source providing harmonized census data from more than 100 countries worldwide

Climate

- **Climatic Research Unit – UEA**
  - Combined land [CRUTEM5] and marine [HadSST4] temperature anomalies on a 5° by 5° grid with greater geographical coverage via statistical infilling

- **Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS)**
    - Open-source data on precipitation capturing millimeters of rain per month (mm/month) at a spatial resolution of 5 km
- **Global Historical Climatology Network Climate Anomaly Monitoring System (GHCN CAMS)**
    - Land surface temperature (LST) capturing mean land surface temperature (LST/month) at a spatial resolution of 50 km

(2) Micro-Level Data

Migration flow

- **International Organisation for Migration (IOM) Flow Monitoring Registry**
    - Collects information on the volume and basic characteristics of populations transiting during observation hours at selected Flow Monitoring Points (FMP). Trained enumerators briefly survey each group of travellers and collect disaggregated information about individual demographics and vulnerabilities.

– Survey data

- **Living Standards Measurement Study (LSMS)**
- Includes longitudinal data for Uganda, Ethiopia and Tanzania. For example, Uganda National Panel Survey 2019-2020 covered the topics:
    - **HOUSEHOLD**: including Household roster, General information on household members, Education, Labor force status, Housing conditions, water and sanitation, Energy use, Other household income, Non-agricultural household enterprise/ activities, Household assets, Household consumption expenditure, Shocks and coping strategies...
    - **WOMAN**: Household identification particulars, Age and marital status...
    - **AGRICULTURE**: Current land Holdings and land that the household accessed through use rights, Agricultural and labour inputs, Crops grown and types of seeds used...

2.2 Data mapping exercise – IGAD region

The first phase of the 'Development of a Modelling Technique for Human Mobility in the Context of Climate Change and Capacity Development in the IGAD Region' project was a mapping investigation into existence and availability of data that could inform, and provide a foundation, for modelling the impacts of climate change and variability on pastoralist and agro-pastoralist communities across the IGAD region.

The data mapping exercise took place between October 2021 and August 2022 and focused on identifying and access data that would provide insight into:

- Environmental stressors that cause pastoralists and agro-pastoralists to undertake adaptive migration due to stressed livelihood conditions – particularly triggering movement across (international) borders
- Conditions under which populations are forced into a 'crisis mode' resulting in livelihood collapse, triggering 'forced' displacement and/or abandonment of livelihoods

The conceptual approach that informed the data mapping exercise is described in figure 3. The overarching aim of the data mapping exercise was to identify and access sources of historic data that could form the basis of developing modelling approaches.

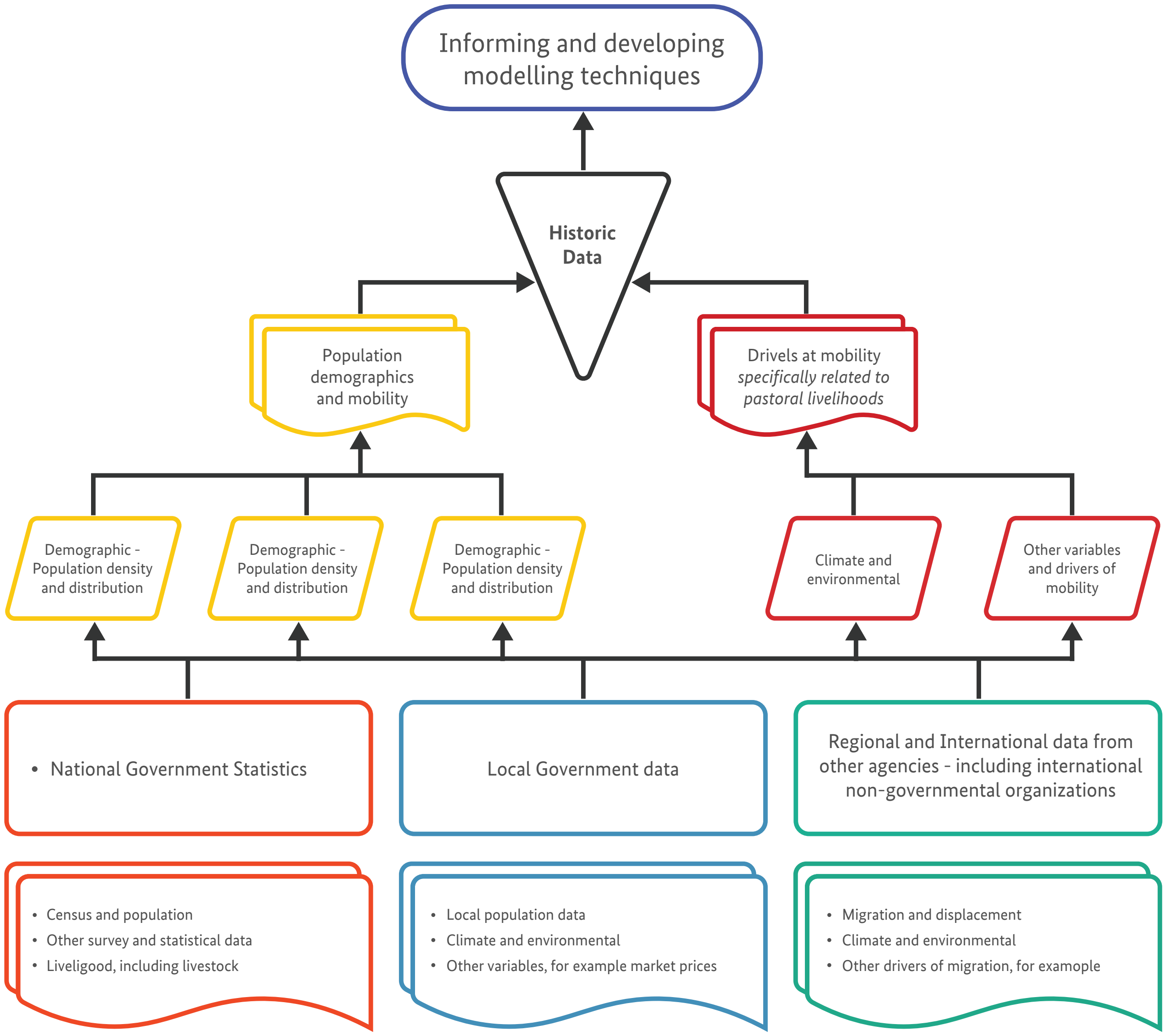


Figure 3. Conceptual approach for the data gathering exercise

The findings of this exercise are detailed in the separate Data Report (September 2022). A summary of these are provided below.

2.2.1. National Government

Potential sources explored:

- 'Ethiopian Statistics Agency of Ethiopia' (https://www.statsethiopia.gov.et/)
- Kenya National Bureau of Statistics (KNBS) (https://www.knbs.or.ke/)
  - Open Africa website (https://open.africa/organization/knbs)
- Government of South Sudan is the National Bureau of Statistics (SSNBS) (https://www.ssnbss.org/)
  - 'Open Data for Africa' (https://southsudan.opendataforafrica.org/) - aggregator for Sudan data sources from other agencies, such as African Development Bank Group (AfDB) and the Common Market for Eastern and Southern Africa (COMESA)
- Uganda Bureau of Statistics: https://www.ubos.org/microdata/index.php/catalog/central

National government sources primarily focus on census and population data. The frequency of these – usually every 10 years – is not sufficient to build useful time series of mobility and population shifts for analysis of the contribution of slow onset climate events such as droughts.

Alongside these, other demographic datasets include National Household Surveys which can provide a thorough 'snapshot' of wider populations, but these tend to be irregular and not focused on the specific populations that are the subject of this study.

More widely, some nations have information on livelihoods and incomes, such as annual agricultural sample surveys (Ethiopia) and Distribution of Households Rearing Livestock (Kenya). These tend to be sporadic, however, and there is little consistency between nations. It is unclear whether this represents a lack of data – or that data is not publicly accessible.

2.2.2. Local government

Local or regional government data, at an Admin 1[42] or sub-regional level is difficult to access as it is generally not hosted online. Accessing such data depends on face-to-face meetings with key individuals who are part of, or who have established networks, with key organisations.

Consequently, it was not possible to access this data through the initial data mapping exercise. As part of the survey activity (detailed below) enumerators in Moyale were instructed to explore the availability to such data locally. There findings highlight the difficulties in accessing such data, as well as the regional differences in availability and collection.

For example, in Kenya data is collected at the regional level, particularly through the NDMA. Data held by the NDMA includes:

[42] Admin levels are a hierarchy system to explain different concepts of administrative boundaries. For example, a city may belong to a municipality, which belongs to a country. Levels help us explain this hierarchy.

- Monthly bulletins from 2013-2022 with all 12 months, long and short rain assessment report
- Rainfall performance from 2010-2022 from Moyale meteorological department
- Rainfall performance from 1981-2022

This data is only available, however in report formats, not as original datasets.

In contrast, in the Ethiopia regions of Somali and Oromia, very little local data is available. Many of the records held at a local level in these regions was destroyed by 2018 violence. The irregularity and poor availability of data which is still retained is exacerbated by high staff turnover, and the lack of computers or WIFI for the data storage and management. Most data records are also held in local languages of Somali and Oromo and therefore needs translation. More generally there is 'fatigue' amongst local government officials about all donors doing several assessments but with delivery as very little especially during their difficult times

2.2.3. Regional: Data from other agencies

Regional data sources explored included those managed by multi-national bodies such as IGAD'S Climate Prediction and Applications Centre (ICPAC), IGAD's Centre For Pastoral Areas and Livestock Development (ICPALD) and IGAD's Conflict Early Warning and Response Mechanism (CEWARN).

Both the ICPAC 'East Africa Hazards Watch' (https://eahazardswatch.icpac.net/) and 'East Africa Drought Watch' (https://droughtwatch.icpac.net/) provide detailed assessments and forecasts for IGAD region environmental, agricultural, climate and livelihood conditions. These are both hosted in user friendly graphical GIS interfaces.

For both portals, links are available to source datasets to facilitate the user accessing historic data – for example, the monthly precipitation Climate Hazards InfraRed Precipitation with Station Data (CHIRPS) information page on the 'East Africa Drought Watch' site links to the Climate Hazards Group (University of California at Santa Barbara). Although this is potentially useful, datasets are commonly held in raster formats, and often not at a scale commensurate with migration data. It should also be noted that although these sites are managed and hosted regionally, much of the data is derived from international, and particularly satellite, data sources and proxies.

Where there is a significant lack of data is on livestock numbers and mobility, which is one of the variables that is key in understanding the impact of dry periods on livelihoods.

2.2.4. International: Data from other agencies

Most of the climatic and environmental data used to map and detail seasonal conditions is derived from satellite or proxy measurements and collated by international research agencies. For example, NDVI data is derived from satellite imagery and accessed through the National Oceanic and Atmospheric Administration (NOAA) in the US, whereas precipitation is derived by Climate Research Unit (CRU) in the UK. These datasets are usually large scale – often global, although some information such as historic precipitation measurements can be accessed at a regional or admin level through the CCKP [43]. The size and complexity of these datasets mean that they require programming expertise to access and download, and then extraction of specific regional data.

[43] https://climateknowledgeportal.worldbank.org/

3. Survey development

The initial results of the data mapping exercise highlighted the lack of pre-existing data in the region, specifically that detailing patterns of migration and displacements. In response to the this, the project partners commissioned a survey of households across the Karamoja and Moyale Moyale cluster cross-border regions. This focused on capturing a migration histories of pastoralist households, alongside demographic, livelihood and household asset information, from 1990 to the present day. As such, these data provide key information on human impacts and responses to environmental stressors – particularly extended dry periods and drought – as well as the influence of other drivers of mobility, such as conflict.

In terms of developing modelling techniques, the approach is to analyse this primary data detailing migration histories of pastoralist households in the context of secondary data measuring historic climate and environmental conditions, particularly proxies for pasture quality, and socio-economic conditions including changes in market prices and reports of conflict. The results of the survey analysis are outlined in section 9.

The survey was trialled in April and May 2022 across 350 households in the Moyale / Borana cross-border cluster:

- Kenya - Moyale: 169 households
- Ethiopia - Oromia: 91 households
- Ethiopia - Somali: 90 households

Following this, and initial analysis of results the structure of the questionnaire was amended, and a second phase of the survey was undertaken in the Karamoja cluster during July-August 2022. In this phase, 621households were surveyed:

- Ethiopia - Bench Maji; South Omo: 152 households
- Kenya – Turkana; West Pokot: 88 households
- South Sudan - Chukudum; Greater Pibor; Ikotos; Kapoeta East, North and South: 176 households
- Uganda – Abim; Amudat; Kaabong; Kaabong North; Kotido; Moroto; Nakapirit: 205 households

The survey comprised the following sections:

- Household roster
    - Demographic data of all members living in the household
    - Demographic data of all household members living outside the household but contributing to household income
- Asset register
    - Detail of differing assets held by the household, to indicate relative wealth as well as coping ability

- Livelihood loss histories
  - Surveying respondents experience and memories of livelihood loss
  - Indicators of reasons for this loss, and assessment of financial damage suffered
  - Description of coping mechanisms used, such as use of household savings or loans
- Livestock loss histories
  - Experience of livestock loss, and reasons for this loss – starvation, disease or theft
- Migration histories
  - Histories of migration and / or displacement, whether as a household moving together or individuals leaving the household
  - Capturing and detailing places of destination and alternative livelihoods

The following paragraphs describe the execution of the data collection process as well as the constraints encountered in order to inform future data collection.

The data collection was carried out by local experts recruited for the exercise. Recruitment was based on their experience in the field, particularly in the areas targeted for data collection, as well as their ability to have at their disposal a network of enumerators covering the area of study. The data collection areas were previously defined by the team in charge of the modelling. The consultants in charge of data collection were also consulted for the definition of the data collection areas. With regard to household targeting, the selection of respondents was based primarily on the experience and knowledge of the field of the consultants in charge of the data collection and enumerators. The two guiding criteria for selection were that the households in question be pastoralists and that they reside in areas particularly affected by drought.

The data collection was carried out through GIZ and required a validation of the questionnaire by the services in charge of the application of the rules for the protection of personal data. In order to save time - the use of data collection tools requiring prior validation by GIZ – it was decided that the data would be done through a paper-based format. The questionnaires had to be printed by the local consultants and distributed to their enumerators. This process was difficult to implement, especially in remote rural areas where printing facilities are not readily available. The collected data then had to be entered into an Excel spreadsheet by the consultants and the enumerators. Together, these factors were a major constraint to data collection and sometimes led to delays.

A final difficulty that arose in the collection of data was the challenge in geolocating the settlements where the survey was conducted. Indeed, the settlements of pastoral communities, although increasingly sedentary – with often a base settlement from which transhumance is conducted and to which they return – are rarely represented on maps. Moreover, due to the dynamic nature of the pastoral way of life, some villages are quite recent and therefore, again, absent from the maps.

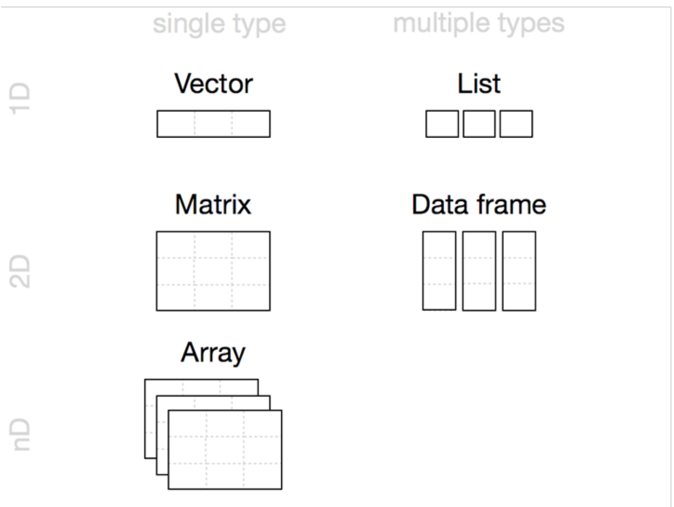
4. Introduction to R and Database Management

R is a software environment for statistical computing and graphics, which provides a well-suited environment for migration modelling and the visualization of results. R is not just a programming language, but it is also an interactive environment for doing data science. To support interaction, it is a much more flexible language than many other programs. Most importantly: It is for free and allows for plenty of extensions making it a suitable statistical software for many applications, including in research on environmental impacts and mobility.

R Studio offers an integrated development environment, which can be used as a complement to R. R Studio offers an interface integrating multiple elements useful for your work. It RStudio divides its world into four panels, including the main console, source code, environment, and further tools windows. Several of the panels are further subdivided into multiple tabs. Which tabs appear in which panels can be customized by the user.

Unlike other statistical software programs (e.g. Stata or SPSS), R relies largely on community-written programs. These can be loaded via packages. An R package is a collection of functions, data, and documentation that extends the capabilities of base R. Using packages is key to the successful use of R. Tidyverse is a family of packages which you can load together in R. They are meant to facilitate the coding process and make code more readable. The packages in the tidyverse share a common philosophy of data and R programming, and are designed to work together naturally

Everything in R is stored as an object which allows for a lot of flexibility in the coding. This makes it very distinct to other statistical software such as Stata. RStudio stores objects in the environment window. The most important type of objects are dataframes which contain different sets of variables in different formats (numeric, character, logical).



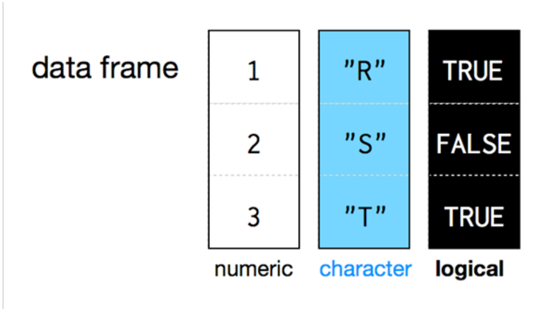


Figure 4. Different types of objects stored in the R environment[44]

[44] Source: https://rstudio-education.github.io/hopr/r-objects.html

Data management is the process of ingesting, storing, organizing and maintaining the data created and collected. Effective data management is a crucial piece of deploying the IT systems that run business applications and provide analytical information to help drive operational decision-making and strategic planning by executives, managers and other end users.

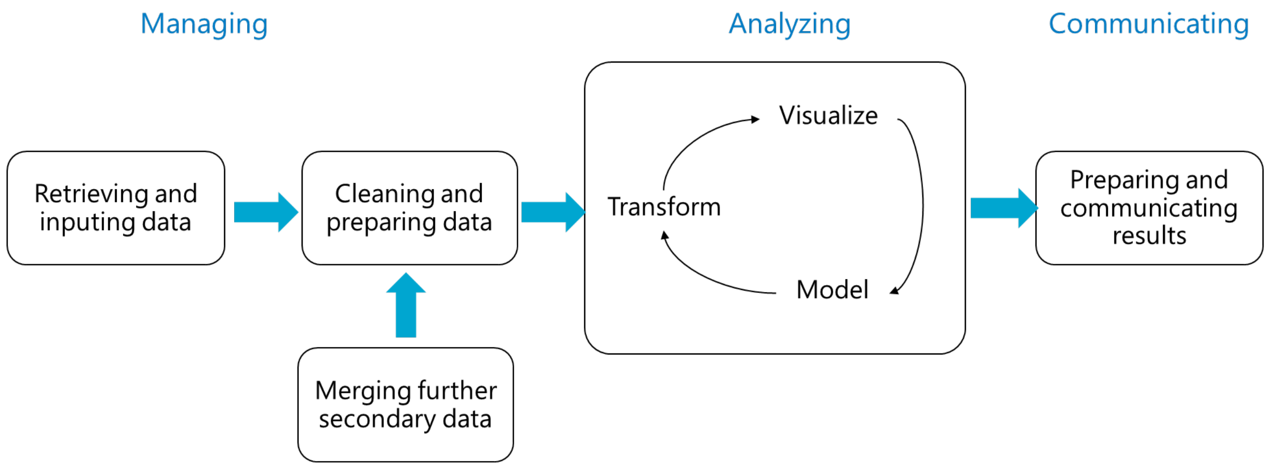


Figure 5. The data management and handling process[45]

Population and migration data are often multi-dimensional, i.e. they are structured along several central characteristics that can be used to describe the data (e.g., spatial and temporal dimension). Especially the temporal dimension offers several advantages for the analysis. Longitudinal data offer several advantages for the measurement and modeling of migration processes and the impacts of environmental changes. Mobility is by its nature a dynamic concept which is influenced by various factors (multicausality) and which is often characterized by high-levels of non-linearity Longitudinal data can help us to better understand how these processes evolve over time and which factors have contributed to the outcomes we observe. For statistical modeling, longitudinal data has another advantage: Under certain circumstances it allows deriving causal estimates for a relationship

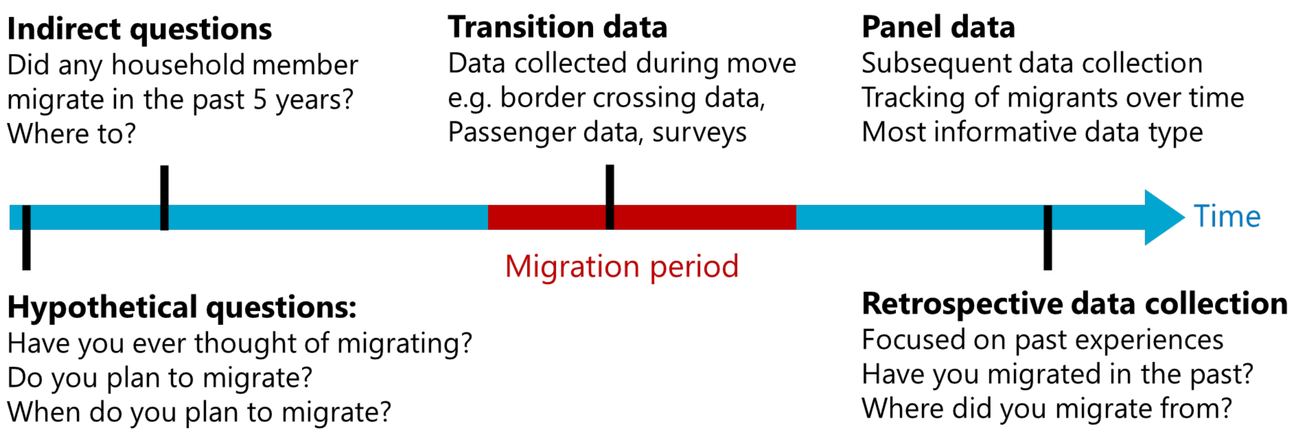


Figure 6. Different ways of collecting longitudinal data on human mobility

[45] Based on: Hadley Wickham and Garett Grolemund: R for Data Science https://r4ds.had.co.nz/

Raw population data often comes in a format that is not yet suitable for data processing and analysis. R offers a number of functions that allow you to effectively change and process data and to make it more suitable to answer your research questions. Variables play a key role here: How can you take the information contained in the raw data to produce meaningful indicators?

Example of preparing a mobility variable based on a household roster (questions about each household member, their characteristics, and their whereabouts). Based on the whereabouts, we can determine if a household member is currently living in the household or is absent for longer time period (=mobility):

- Clean and harmonize data.
- Aggregate information over all household members: How many absent members?
- Derive a final indicator, e.g., a binary measure capturing whether any household member is absent or the total number of household members absent.
- Continue with analysis. Often modelling involves iterative elements. If needed, you can return to step 1 in order to identify alternative ways of generating the measure of interest.

In statistical analyses, several methods for data aggregation and clustering exist that can be a useful pre-processing step before the actual modelling. They all have the goal to capture and present complex and multifaceted information in a comprehensive and concise way

- Cluster analysis
- Factor analysis
- Principal component analysis
- Structural equation modelling

After the completion of the data preparation steps, descriptive statistics are the starting point of every data analysis. Aim: Get information about distribution of key variables and the particularities of the data. Descriptive analyses can be (1) graphical, e.g. bar charts, pie charts, histograms or (2) numerical, e.g. measures of central tendency and dispersion. Which kind of descriptive statistic can be calculated depends on the data and the scale level of the considered variables.

Discrete/Categorical:

- Nominal: No natural order of values of a variable. Examples: eye colour, gender, nationality
- Ordinal: Ordering or ranking of variable values possible; Differences between values are unspecified, unequal. Examples: school grades, education levels

Continuous:

- Interval/ratio scale: Differences between variable values are measurable and clearly interpretable. Examples: age, income, Likert scales

When considering mobility as an outcome, we find a number of operationalizations:

- Binary: Is currently any household member absent? Has the household migrated in past 12 months? Have pastoralists changed their mobility behaviour?

- Count: How many household members are currently absent? What is the flow of migrants between a region A and a region B?

- Continuous: What is the percentage of household members currently absent? How many percent of the population have migrated from region A to region B in past 12 months?

5. Integrating environmental and population data

Environmental and population data, including mobility data, often come in very different formats that need to be aligned in order to determine environmental impacts on mobility. Spatial dimension: Environmental data are often provided in a grid-cell format. Population data are typically at the level of administrative areas or linked to GPS coordinates. Temporal dimension: Environmental data are often provided in a high-frequency format, often yearly or monthly (or even daily or hourly). Population data is typically collected in longer intervals. This has important implications both for the integration of data and the modelling as environmental data often provides a richer data format compared to population data

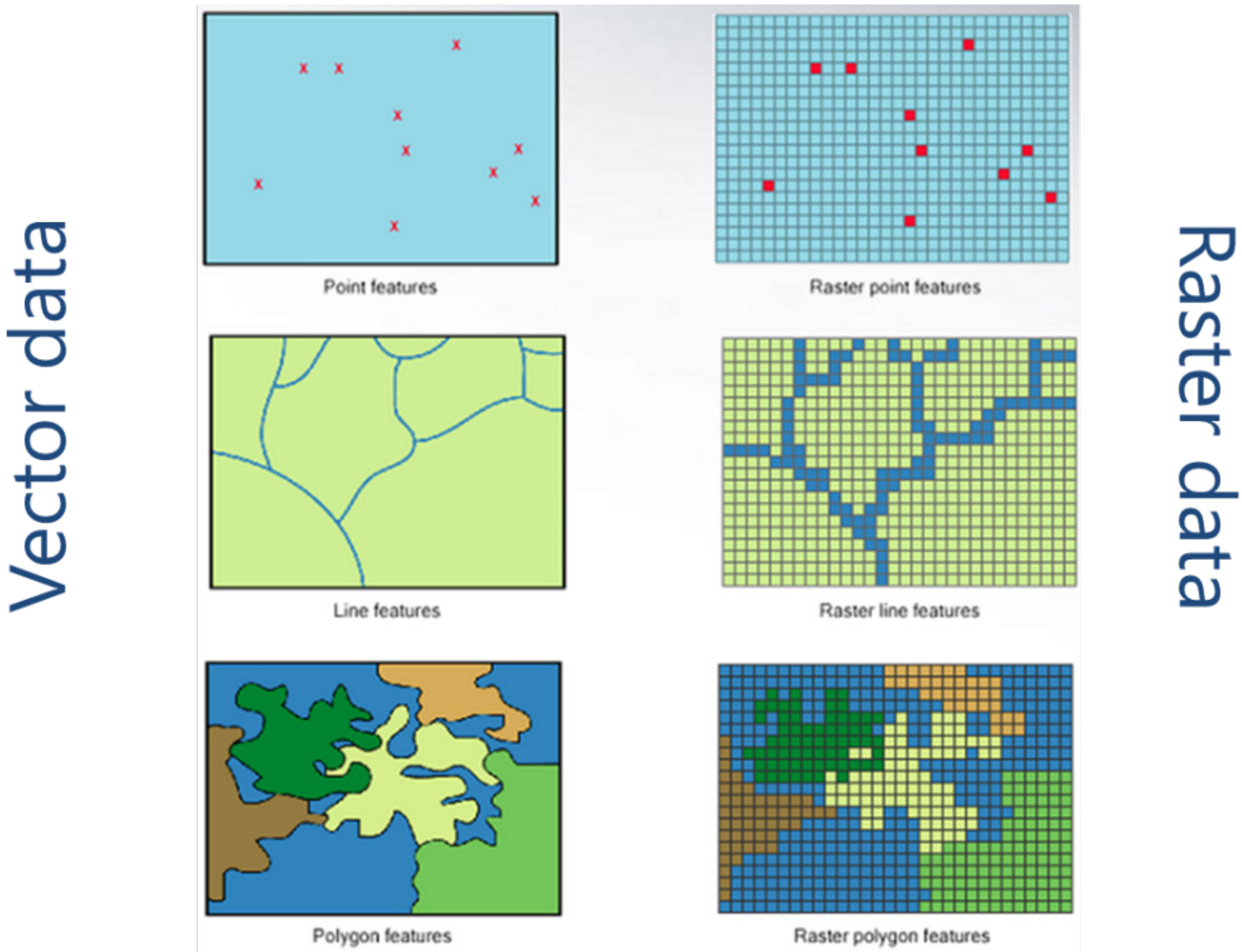


Figure 7. Different geospatial data formats[46]

After extracting information from raster grids, we obtain data on environmental/climatic conditions in regions/communities, typically at different time points. This data can be directly combined with the population and mobility data, allowing us to explore impacts of environmental factors on mobility outcomes and processes. This is when the actual work begins...

[46] Source: Wasser et al: Introduction to Geospatial Raster and Vector Data with R

There are different possible ways how environmental data can be processed and aggregate to meaningful indicators reflecting different levels and intensities of environmental stress, including deviations from long-term means, anomalies based on deviations from long-term mean, threshold specifications, e.g. heat day if temperature > 30°C, indices, e.g. SPEI drought index, composite drought index (CDI), and cumulative measurements, e.g. number of consecutive heatdays, drought seasons. The impact of environmental events may only materialize over time or may otherwise affect mobility decisions in non-linear, evolving ways. Problem: We often do not have a good theory to understand these processes over time.

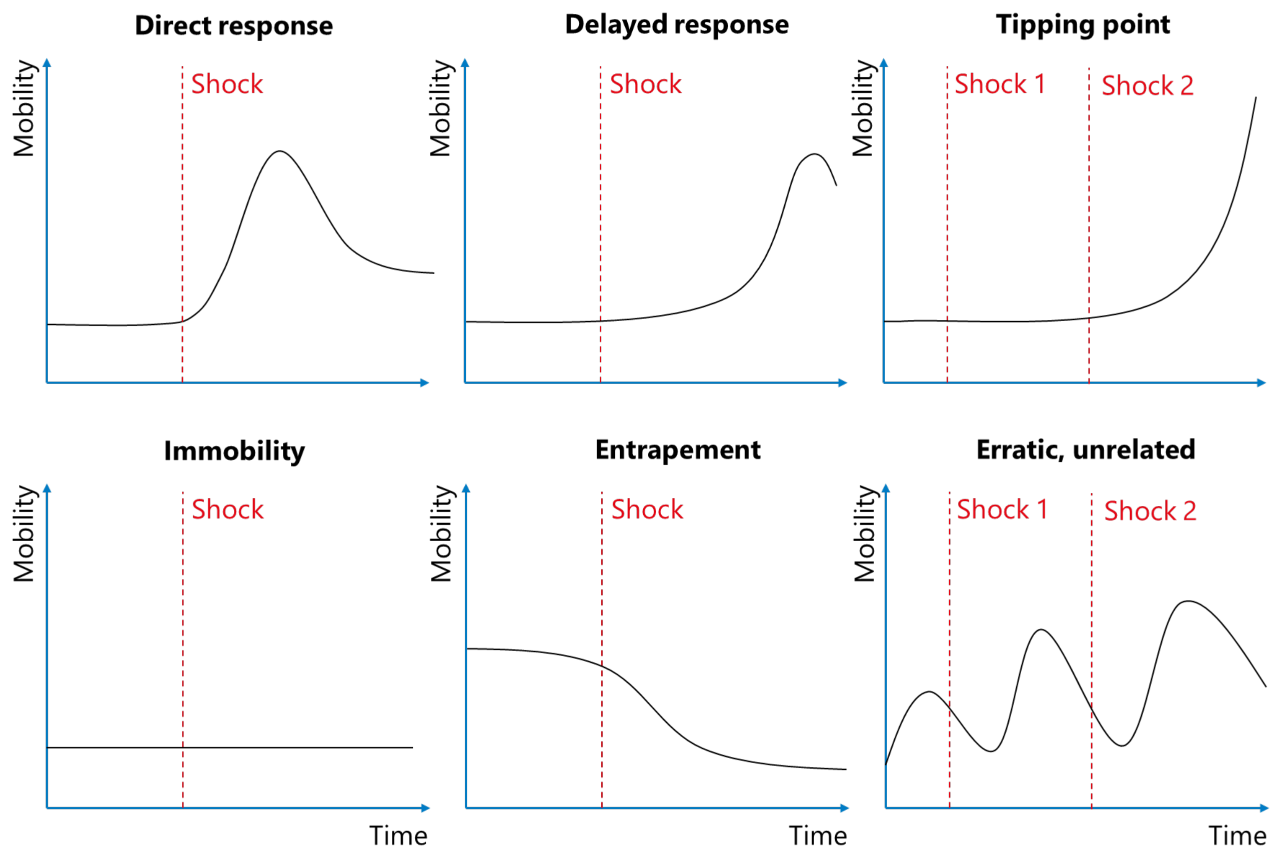


Figure 8. Different mobility response patterns over time

A number of conceptual questions have to be answered for the integration of environmental and population/mobility data to be successful:

- What are appropriate time scales to measure climatic impacts?
- How aggregate should these be reflected?
- Are there potential spatial spill-over effects?
- How is it possible to best reflect local climatic impacts?

Often, there are no one-size-fits-all solutions. Instead, it is recommendable to try out different operationalizations of environmental hazards (e.g., over different time horizons) and different ways to model their impacts on mobility. General recommendation: Taking a pragmatic approach. Having different data versions allowing you to flexibly model processes over time.

6. Modelling the climate-mobility nexus

6.1 Basic idea and concepts

Having established the data availability and descriptive statistics of the macro drivers of migration, the obstacles to and facilitators and the micro factors affecting the link between climate variability and change and migration, the next step is to model the relationship between the two. A number of model types are relevant for this and the choice of which one to use depends on the objective of the project or research. The following section largely taken from IDMC (2022)[47] highlights the typical model types used in modelling the climate-mobility nexus. Before outlining the different types it is worth considering why someone may want to model the nexus. Foremost modelling the nexus allows the identification of the relative contribution of a climate hazard on mobility. Modelling also allows us to understand the other factors that contribute to mobility. This information is important to understand the factors that cause and exacerbate ongoing migration and displacement.

Furthermore some models can be used to explore the potential impact of policies or interventions aiming to prepare for or reduce migration. Models can also be used to explore the dynamics and patterns of future mobility associated with different climate change scenarios and to inform future data collection efforts. Figure 9 from IDMC (2022) shows the distribution of the uses of different models of drought displacement from a literature review of 42 publications in 2022. The following text in this chapter is largely adapted from this publication. Most of the publications reviewed in this study (29/42) indicated that modelling was used to test whether climate, environmental, socioeconomic, or other factors have an influence on human mobility, and to quantify this evidence to improve our understanding of such phenomena. For this purpose, statistical regression was the most common modelling method used. The second most common use of drought displacement models was based on scenario simulation. Here models are used to explore the outcomes of plausible responses to drought under different (including climate change) scenarios of the drivers. Only one model was used to forecast mobility and this was based on time-series analysis

[46] https://www.internal-displacement.org/publications/drought-displacement-modelling

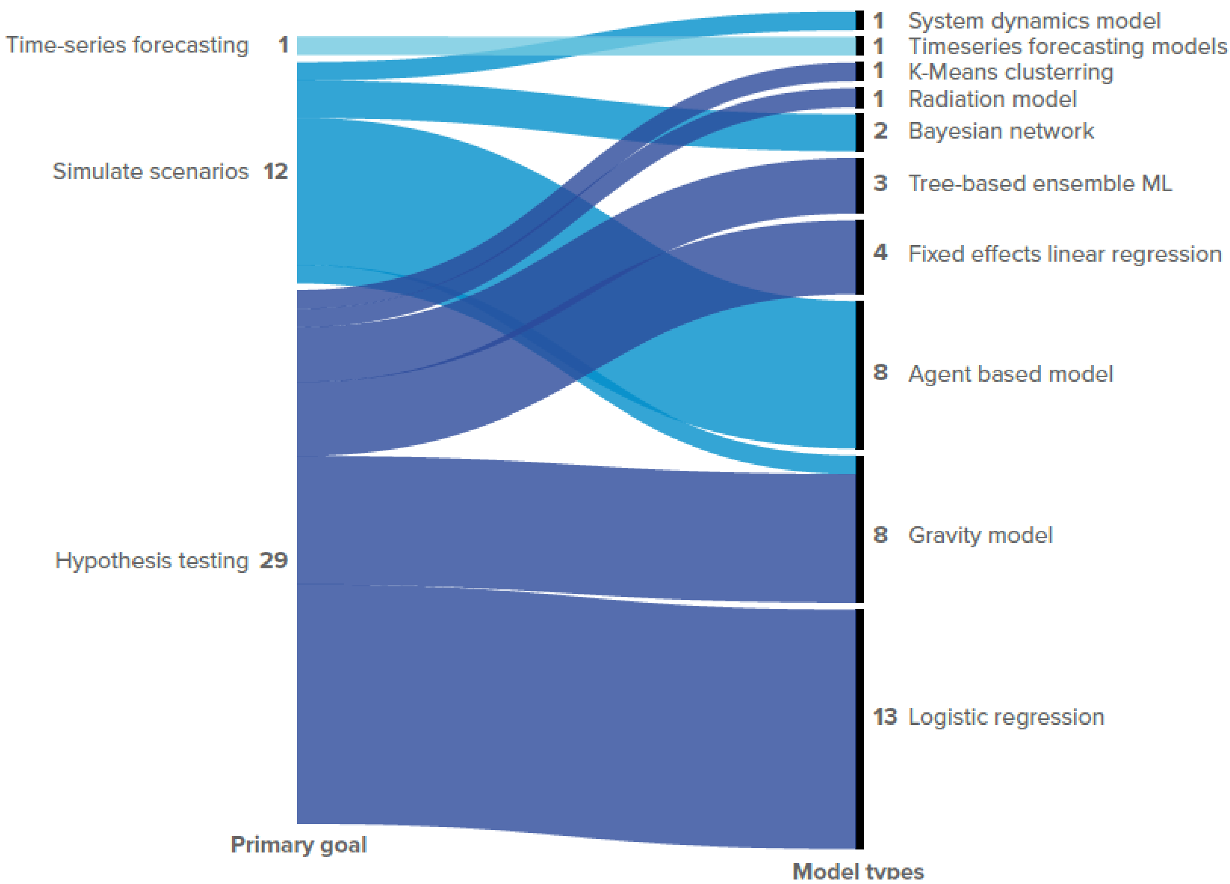


Figure 9. Goals of reviewed drought mobility models and stated applications from IDMC (2022)

6.2 Time-series models

Time-series models are based on sequence of observations over a period. In time series analysis it is important to understand the behaviour of variables, their interactions and integrations overtime, while accounting for any fixed effects in the data. The steps for analysing time series consist of obtaining the structure and underlying pattern of the observed data, and then, finding a model (usually a regression) to make future predictions[48]. Regressions can be also form the basis of machine learning in this sphere. The most notorious example of the application of this methodology to model displacement is the UNHCR's Project which explored the movements of both internally displaced people (IDPs) inside Somalia and refugees crossing the border to Dollo Ado region (southern Ethiopia).

The advantages of time-series models are that they can jointly measure the association of variables, to account for confounding effects when variables are included in the analysis. The results or the model are interpretable: coefficients in the model can be seen as "strength factors" of covariates on human mobility. They allow for binary targets, meaning that survey and census data can be easily exploited. Lastly, they are computationally efficient.

[48] Shrestha, M.B. and Bhatta, G.R., 2018. Selecting appropriate methodological framework for time series data analysis. The Journal of Finance and Data Science, 4(2), pp.71-89.

The disadvantages of time-series models are that they do not work well with data that is not linearly separable, which means that it cannot account for the more complex non-linear relationships present in displacement. They also have problems with small sample sizes which can invalidate the coefficient results if too many variables must be included in the study (also known as the curse of dimensionality). If covariates are intercorrelated and this is not controlled, then the regression coefficients can be affected and invalidate the results of the study.

6.3 Systems Dynamics models

System dynamics (SD) models aim to simulate complex phenomena using causal models that represent a system and its behaviour over time. SD models represent aggregated systems in the form of stocks, flows, feedback loops and time delays. The advantages of SD models are:

- They are potentially useful when trying to study how macro-level conditions (made up by designed rules) give rise to micro-level interactions.
- SD models can simulate complex dynamics such as non-linear effects, feedback loops, autoregressive effects, and the emergent and adaptive behaviour typical of mobility dynamics.
- SD models can be computationally very efficient in comparison with ABMs (a matter of seconds vs. simulations potentially requiring days, depending on the complexity of the model).

The disadvantages of SD models are:

- Defining the system's components and interactions can be a time-consuming task and subject to the bias of the modeller, particularly when there is no clear understanding of the system (e.g., how does conflict affect water availability?) or when the underlying social theory is not precise.
- SDs equations must be designed to fit the real system's complex behaviour. The inherent complexity of mobility dynamics means that it is difficult to capture every relationship, making their mathematical representation complicated. This also requires a precise underlying social theory and expert knowledge of the context.
- SD models require an extensive amount of parameter adjustment and calibration: the causal links, the quantification of the relationships between the variables and the time-lags in which the different variables affect one another must be calibrated.

The project explored one particular SD model for the region, the IDMC or SODRD model. This model follows the conceptual framework outlined by Ginnetti and Franck[49] in that identifies there is a causal relationship between rainfall and displacement involving the following logic:

- Less rainfall because of more droughts causes a decline in pasture productivity
- Availability of less fodder in turn increases livestock mortality which shrinks the livestock population. Pastoralist income then decreases from declining livestock and milk sales.

[49] Ginnetti, J., Franck, T., 2014. Assessing drought displacement risk for Kenyan, Ethiopian and Somali pastoralists. Norwegian Refugee Council - Iinternal Displacement Monitoring Centre, Geneva - Switzerland.

- When herd sizes reach the critical threshold necessary for subsistence, pastoralists are (temporarily) unable to support their livelihoods
- Displacement of pastoralists increases during these periods

The system understanding underlying the model is shown in Figure 10. While the following text is taken from the unpublished Final report prepared by: Khaled Gaafar and Maria Teresa Miranda

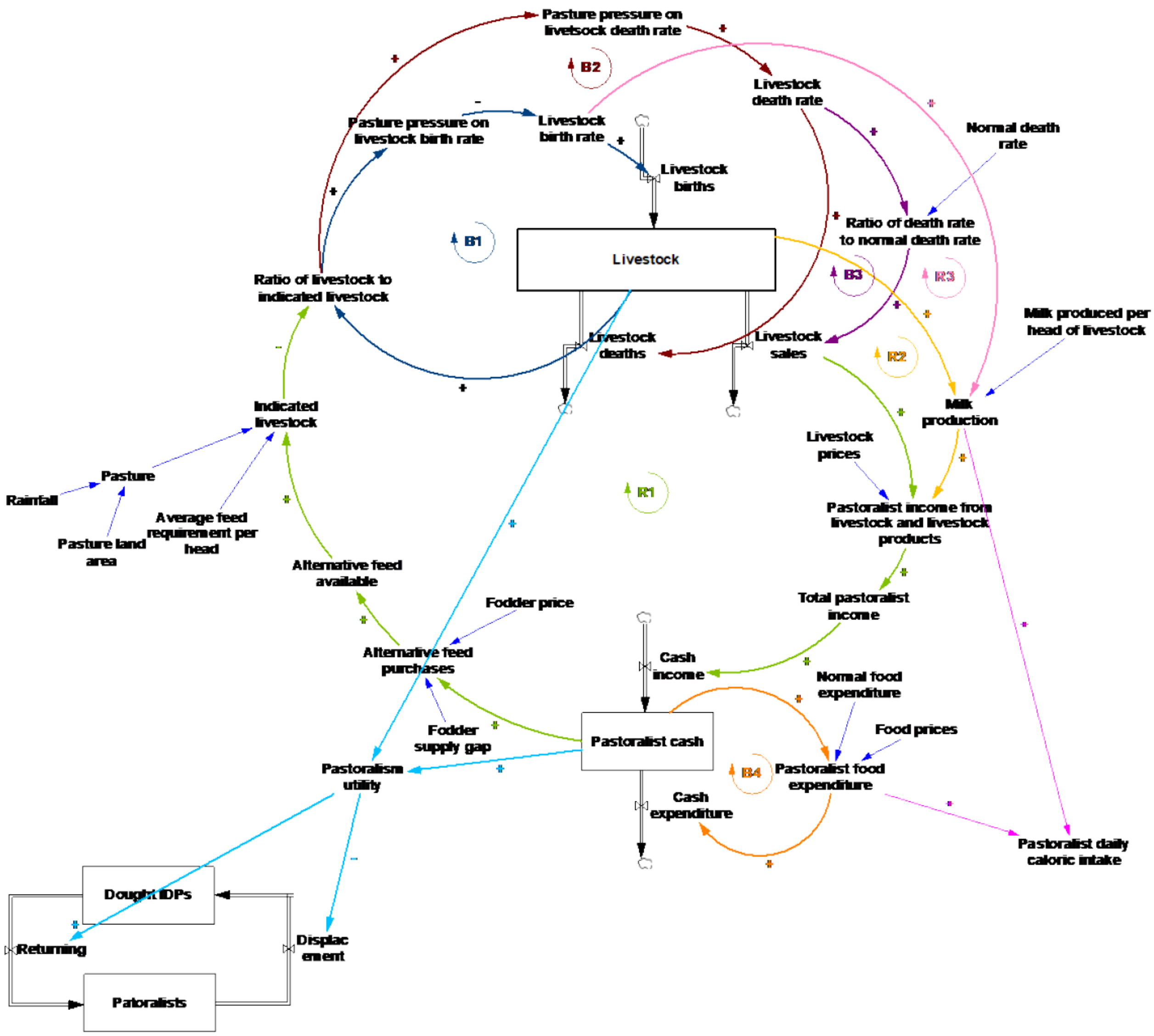


Figure 10. Causal graphic of the interactions between drought, livelihood, nutrition, and displacement in the SODRD model.

The SODRD model was developed by IDMC for the Danish Refugee Council. The aim of the model was to serve as an interactive scenario simulator to understand and explore the drivers of pastoralists forced displacement in Somalia and Ethiopia, as result of drought conditions. The SODRD model is primarily based on the impact of rainfall on pasture growth. In the future the model could be extended to include the role of groundwater, temperature processes and invasive species to improve the representation of the quantity and quality of pasture available for livestock. Pasture is important to sustain livestock populations. The stock and flow diagram outlines the key feedback loops stabilizing livestock populations. More pasture means livestock have more food to grow. Less pasture means more livestock will die, less will be born, and pastoralists may engage in de-stocking activities if the shortage of pastures is severe. The loss of livestock is catastrophic to the pastoralist livelihood as livestock provides the primary revenue source to pastoral households.

The model compares pasture available to feed requirements given herd sizes in each livelihood zone, thus the variable “indicated livestock”. Boxes in Figure XX represent stocks represent state variables which accumulate the net difference between flows. Livestock is a stock, while births, deaths, and sales are flows. If the pasture is extensive and rich enough to sufficiently cover herds’ requirements then livestock birth rates are normal. Conversely, death rates increase if pasture is insufficient to cover for the feed requirements of livestock herds reflecting competition over scarce resources (B2). That loop is balancing as it controls the livestock population in instances of insufficient resources. Both balancing loops here are goal seeking, in the sense that they aim to match the herd size to the indicated herd size from pastures available. Pastureland area is a key variable since pasture availability is a function of both rainfall, and accessible rangeland which could get blocked, or degraded over time. Feedback loops are the building blocks of dynamic models.

A third balancing loop represents the de-stocking activities of pastoralists in times of distress (B3), whereby pastoralists sell more livestock during times of stress to sustain the herd given the resources available. In times of drought, due to the action of the three aforementioned balancing loops livestock populations begin to decline in proportion to the gap between feed requirements, and pasture available. The common coping strategy to pasture unavailability is migration (hence the term nomadic pastoralists). The original model assumes free movement of pastoralists within the boundaries of each FSAU determined livelihood zone but excludes cross-zone and cross-border migration of pastoralists due to quantification challenges. Data collection could help parametrize the model for cross-zone and cross-border migration.

Around 2/3rds of pastoralist income are derived from livestock sales. The second most important source of income is from the sale of livestock products such as milk. Livestock sales are affected by the livestock death rate. In times of drought, as herds face a higher risk of decimation due to resource scarcity, pastoralists sell more livestock to preserve the core herd, and to increase their cash income in order to purchase alternative feed (R1). Ideally by doing so pastoralists can support their herds, activating loops (B1) and (B2) to increase births and reduce deaths so the herd is sustained. In reality, however, the spike in livestock supply usually causes livestock prices to fall, while prices of alternative feed spikes. If there isn’t enough alternative feed to cover for the livestock feed gap, or if there isn’t enough cash to purchase such feed (R1) may be undermined as a virtuous cycle countering the effects of (B1) and (B2).

This is important since pastoralists may have to make tough choices if cash is insufficient such as reducing their food expenditure. Loop (B4) represents the adjustment of spending on food as a result of lack of cash. Such cash is a factor of the previously mentioned feedback loops of livestock sales, and milk sales. Other income sources such as temporary wage labor and remittances are included in the model but were excluded from the diagram(s) for simplicity.

While SODRD represents the primary socio-ecological processes for many pastoralists it neglects to include the important social processes of rangeland management that impact pasture and water resources. These traditional structures for drought risk management are important in pastoralist livelihoods.

6.4 Bayesian network models

A Bayesian Network (BN) is a probabilistic tool characterized by two parts: its structure and its parameters. The structure represents the causal connections between the variables of the network, while the parameters represent the conditional probabilities between the variables (i.e., a BN uses the fact that "X often causes Y"). Both parts need to be inferred from expert knowledge or estimated from data. The ultimate objective of a BN is to estimate the joint probability distribution (all events in the system happening together) of the system. This allows for an answer to questions such as "what is the probability drought displacement occurs (X) given below average rainfall (Y) when there are conflicts in the area (Z)?".

A key strength of the use of Bayesian Networks (BN) in the field is that they can explicitly handle uncertainty and can work where data is missing or inconsistent. The advantages of BNs are that their construction is flexible in the sense that the causal graph can be constructed from expert knowledge or alternatively, derived from data, and then used to estimate the probabilities of the causal events. Estimating the structure of the network from observational data is difficult, but it can help discover unexpected relations between the variables. Once the network structure has been learned, a BN can be used not only for observational inference but also for interventional reasoning, meaning that we can ask the models questions like "can we stop X from happening if we decrease Y?". However BNs suffer that they cannot include closed loops or feedback effects between variables and relationships and are unidirectional.

- Local Government/Authorities Monitoring reports of the project interventions.
- Online surveys if the technology and culture of the communities under support allows both women and men participation.

6.5 Agent based modelling (ABMs)

Agent-based models were recently introduced in the field to simulate mobility dynamics emerging from the behaviour of many interacting agents (e.g. individuals or households) by explicitly accounting for the rules by which the agents interact. They are useful when trying to model how individual behaviour gives rise to population-level patterns or possible adaptive strategies from socio-ecological feedbacks. ABMS involve treating households or individuals as agents who are located not only geographically but in terms of their social networks. These social networks attempt to simulate interactions between agents.

The strength of ABMs is that they simulate mobility using rules which generate artificial data and patterns the modeller wants to simulate, they can tackle problems which could demand unrealistic amounts of data concerning individual interactions and which could not be studied otherwise.

ABMs allow for interventional analysis to observe how changing a variable can affect mobility dynamics in different situations and in specific moments in time. ABMs allow for interactions, non-linear effects, feedback loops, autoregressive effects, and emergent and adaptive behaviour typical of mobility dynamics. ABMs are stochastic by nature. They can deal with associated uncertainties of mobility dynamics and return different scenarios for analysis. However, they suffer from the following disadvantages:

- Validation of ABMs requires real world data comparable with the artificially generated data which might not be available.
- Another caveat is that ABMs require an extensive amount of parameter calibration and defining of the interactions driving the system. This is a particular problem when considering parametrizing the social network.
- ABMs also demand high computational power to return simulation results that are not appropriate for real-time policy discussion.
- The conceptual design of the model that matches the real dynamics of human mobility may be challenging to implement. This is because the capturing of the fundamental rules that give rise to the mobility dynamics may require a robust and precise social theory.

6.6 Conclusions

A variety of different models can be used to understand and simulate the climate-mobility nexus. These range in complexity from regressions, Bayesian Networks, machine learning, systems dynamics model and agent-based models. Each of these have advantages and disadvantages in particularly around how portable they are to different regions and conditions. They also have different uses ranging from forecasting to policy planning. In terms of forecasting all of the above can be used.

7. Results of the data analysis

7.1 Analysis approach

i. Results from the surveys were uploaded by local enumerators into combined datasets

ii. These datasets were then cleaned, with any anomalies or inconsistencies addressed in subsequent meetings between project team and lead enumerators

iii. Datasets from individual surveys were combined

iv. Initial analysis of these datasets was undertaken to identify temporal trends in, and relationships between, livelihood loss, livestock loss and displacement

v. Patterns of livelihood loss, livestock loss and displacement were then analysed with reference to historic climate and environmental data indices to identify correlations and develop modelling approaches

7.2 Results of data analysis - Overview

- Based on the surveys from 2010 to 2022, the incidence of drought experienced by a household gives on average an 11% increase in the likelihood of displacement (when controlling for conflict and livestock disease)
- There is, however, considerable variability with some locations have seen more than 20% displacement with drought, with the impact of droughts on displacement appearing more pronounced in Moyale than Karamoja
- Settled populations show a significantly higher rate of displacement than mobile ones
- There is only a weak but (significant relationship) between objective measures of drought and displacement as exhibited by SPI (but not NDVI)
- Last two years have shown very large displacements compared to previous years according to the surveys
- If household has reported experiencing drought on average they report a $732 livelihood loss per drought event (i.e. the average household loss from 2010-2022 per year)
- This drops to $183 with each unit decrease of SPI, when the drought indicator is SPI

7.3 Results of data analysis

7.3.1. Descriptives on displacement and migration

Analysis of survey data shows that there is temporal trend of increasing displacement over time (Table 1; Figure 11). This is more pronounced over the last two years where there have been very large numbers of displacements in comparison to previous years.

Potentially this 'increase' in displacement over time may be due to 'recency bias'. This is a phenomenon where respondents are more likely to recall and report events that are more recent because their memory of them is clearer. Given the severity, however, of the dry period and drought that has been reported over the last two years, it is likely that this has contributed to high levels of livelihood loss and displacement.

More generally, another contribution to this increase in displacement over time, as suggested by one of the project enumerators in Moyale, is that the last decade has seen the growth of local towns, which has provided more livelihood opportunities for migrants, particularly in casual labour such as motorcycle taxi driving or unloading trucks. The resulting 'pull' has provided the opportunity and encouragement for people to migrate as a form of livelihood diversification.

Table 1: Migration and displacement over time

	Dependent variable:		
	Total	Karamoja	Moyale
year	1.240***	0.674***	0.566***
	(0.333)	(0.240)	(0.175)
Constant	-2,474.655***	-1,343.818***	-1,130.837***
	(668.943)	(481.536)	(350.656)
Observations	33	33	33
R^2	0.308	0.203	0.253
Adjusted R^2	0.286	0.177	0.229
Residual Std. Error (df = 31)	18.240	13.130	9.561
F Statistic (df = 1; 31)	13.819***	7.879***	10.479***
Note:	*p<0.1; **p<0.05; ***p<0.01		

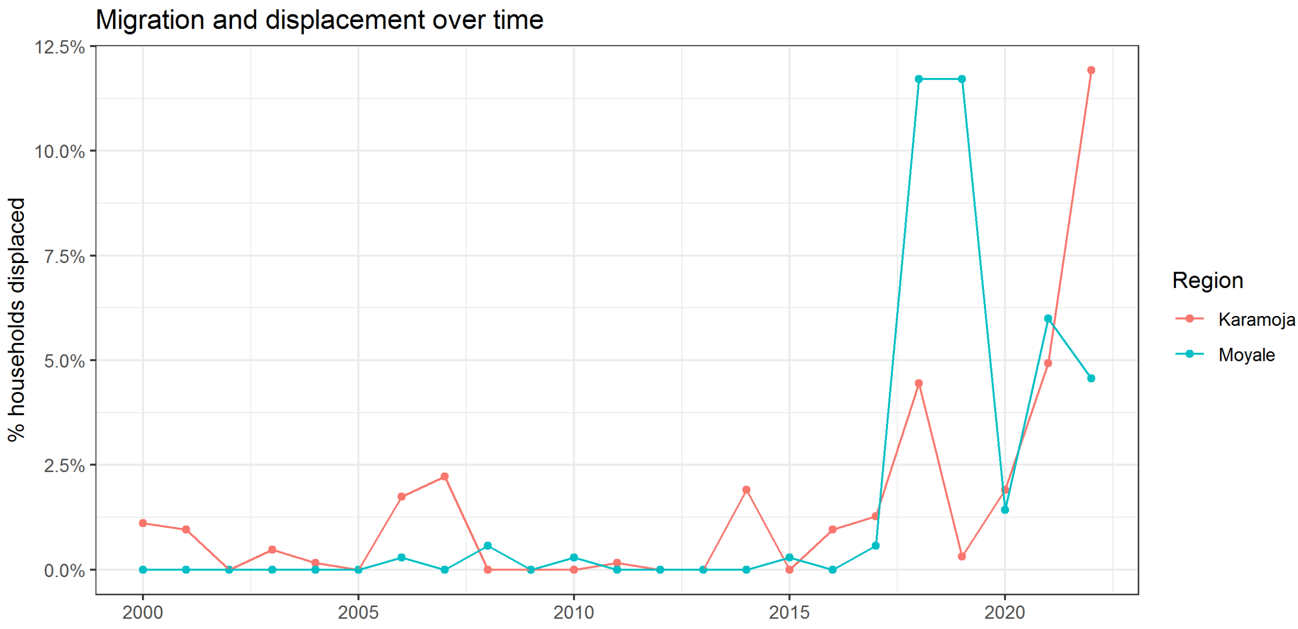


Figure 11: Migration and displacement over time for surveyed households in Karamoja and Moyale clusters

There was very little difference in levels of displacement between the two clusters, as illustrated in Figure 12, with 23% of households in Moyale having experienced displacement as opposed to 24% of households in Karamoja.

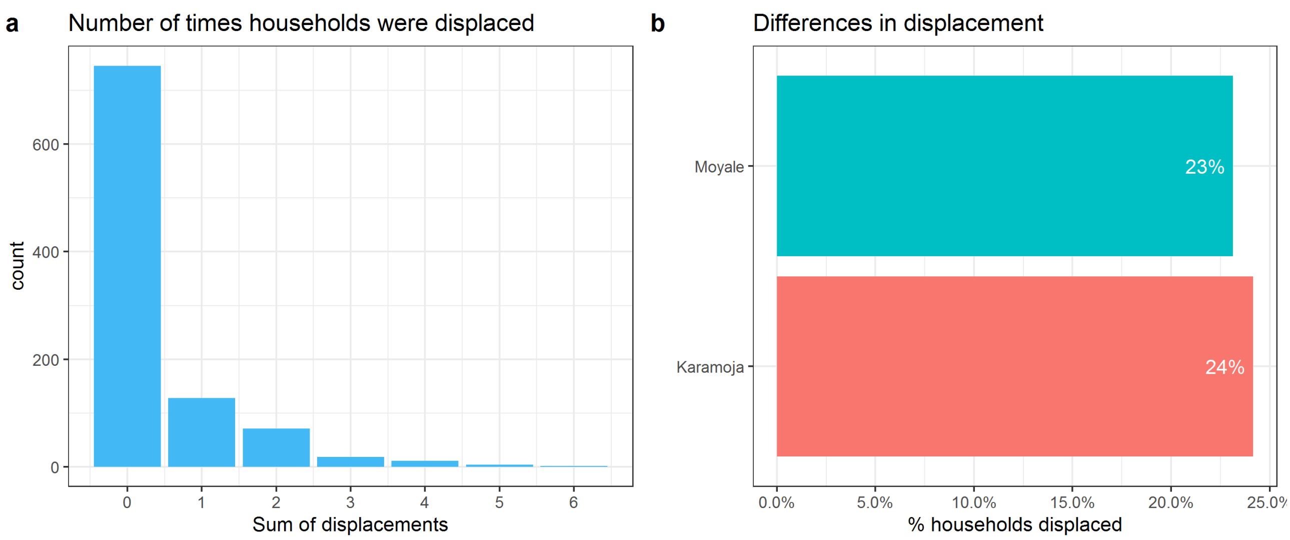


Figure 12: Distribution of displacement in the sample across regions. (a) shows the number of times households were displaced in the period. Panel (b) shows the share of households encountering a displacement in the period for Moyale and Karamoja.

As expected, there is a high correlation between livestock loss and livelihood loss whereas the relationship between livestock loss and displacement, and livelihood loss and displacement is less clear (Figure 13).

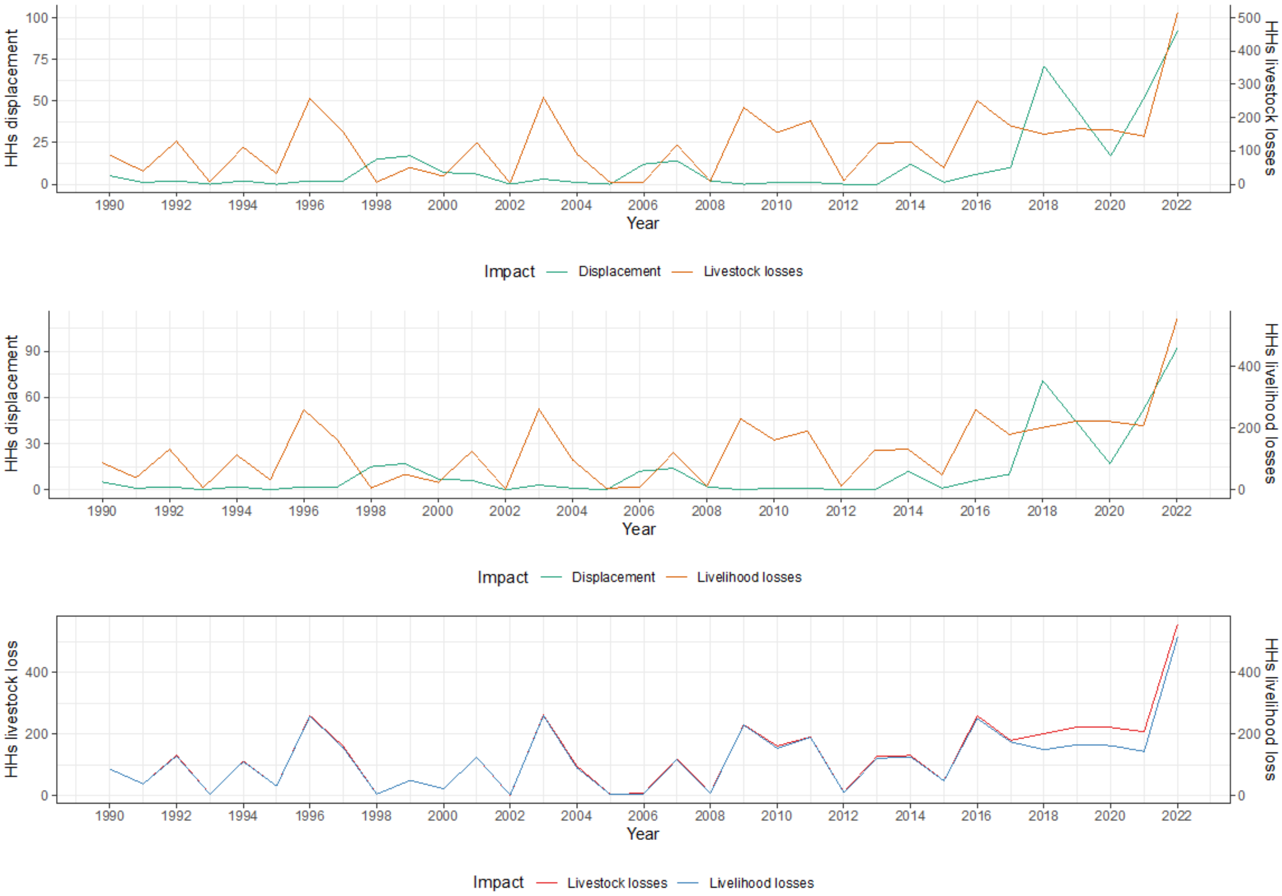


Figure 13: Relationships between displacement, livelihood loss and livestock loss in surveyed households

7.3.2. Drought impacts and displacement

Through the survey, respondents were asked to provide reasons for both livestock loss and livelihood loss. Potential options were drought, loss of pasture, theft of livestock, livestock disease and conflict. Respondents were also given the opportunity to provide an alternative reason which was then recorded by the enumerator.

Based on the surveys from 2010 to 2022, the incidence of drought reported by a household gives on average an 11% increase in the likelihood of displacement, when controlling for conflict and livestock disease.

The impact of differing shocks on displacement was modelled using linear regression. The results of this are detailed in Table 2. Model 1 shows that drought has a positive relationship on displacement, with an experience of drought increasing probability of displacement. Model 2, however, suggests that experience of livestock disease has a negative impact on displacement. Conflict has a positive impact on displacement, as detailed in model 3, whilst model 4 shows livestock theft has a negative impact.

These models suggest that while experience of drought and conflict are likely to increase the probability of displacement, loss of livestock through either disease or theft will decrease it.

Table 2. Baseline models: Impacts of different shocks on displacement at the household level

	Dependent variable: Displacement (Binary)			
	model1	model2	model3	model4
Drought	0.0505*** (0.0050)	0.1088*** (0.0150)	0.0929*** (0.0136)	0.1014*** (0.0136)
Livestock disease		-0.0702*** (0.0149)	-0.0866*** (0.0185)	-0.0059 (0.0184)
Conflict			0.0385*** (0.0144)	0.0901*** (0.0162)
Livestock theft				-0.1532*** (0.0205)
Fixed-Effects:	-------------------	-------------------	-------------------	-------------------
Household	Yes	Yes	Yes	Yes
_______________	______________	______________	______________	______________
S.E.: Clustered	by: q_id	by: q_id	by: q_id	by: q_id
Observations	22517	22517	22517	22517
R2	0.08582	0.09265	0.09483	0.11316
Within R2	0.02092	0.02825	0.03058	0.05021

Note: Fixed effects regression models. Coefficients in cells with cluster robust standard errors in parentheses. P-Values: 0 < *** < 0.01 < ** < 0.05 < * < 0.1

The survey results also highlight that there was a significant variability between locations surveyed. Some regions – Nakapiriprit, Amudat and Somali Dawa - reported more than 20% displacement with drought, as illustrated in Figure 14. In general, the impacts of droughts on displacement appeared more pronounced in Moyale than Karamoja.

There was also a heterogeneity between those households that defined themselves as ‘settled’ as opposed to those that defined themselves as ‘mobile’, with settled populations demonstrating a significantly higher rate of displacement than mobile ones (Figure 15).

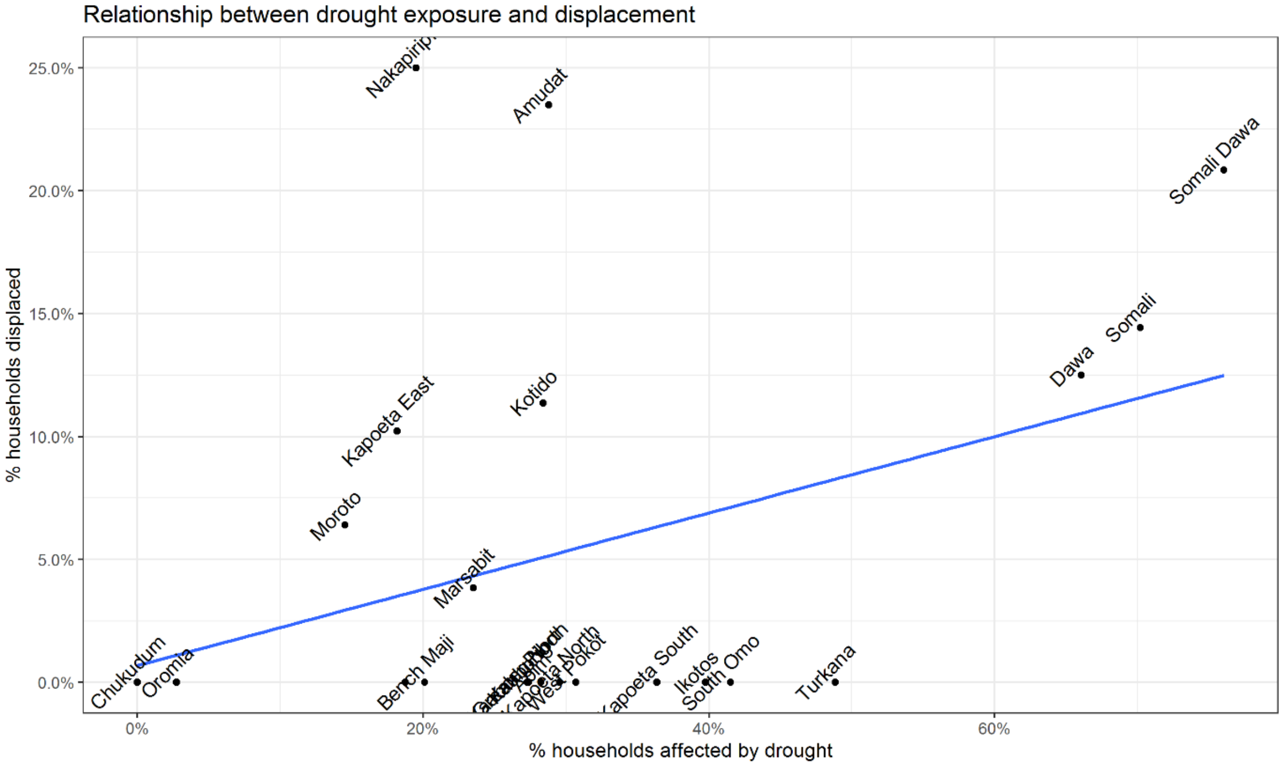


Figure 14: Relationship between drought exposure and displacement across different locations

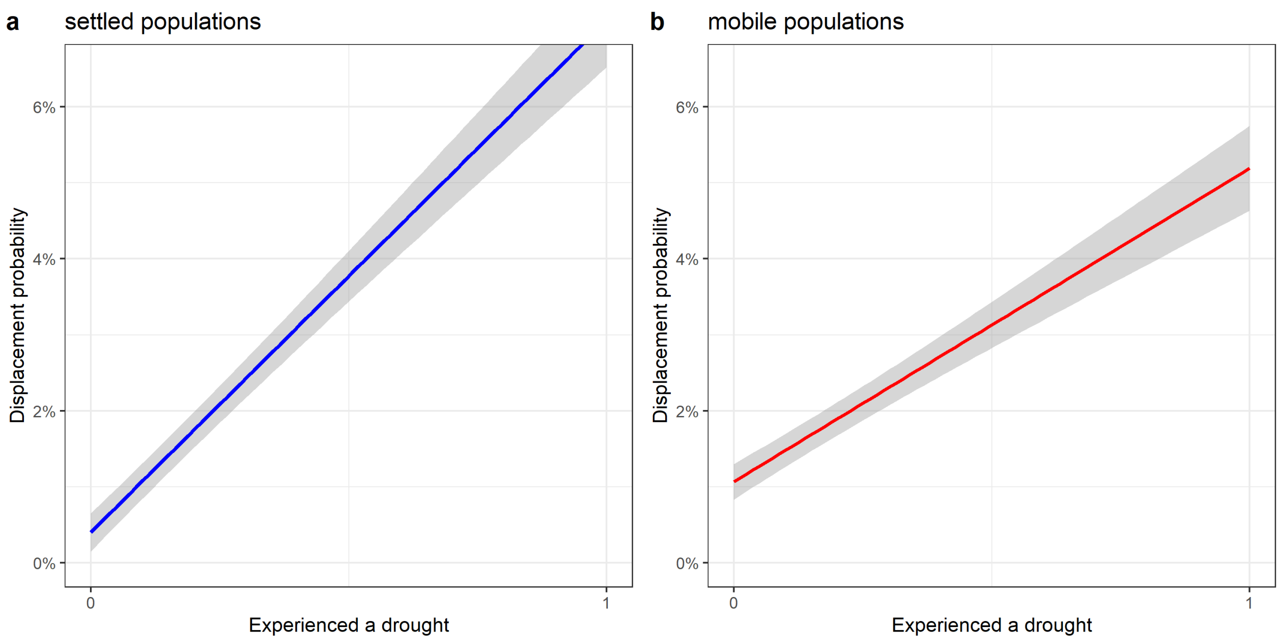


Figure 15: Displacement probability against experience of drought for (a) settled populations (b) mobile populations

The interaction between drought exposure and mobility was modelled for different population groups as detailed in Table 3. Each of the five models demonstrates the relative difference in probability of displacement of that group compared to non-group members in the sample when both experience drought. Hence a homeowner who experiences drought is around 10% more likely to be displaced than a non-homeowner.

This model also highlights the different responses according to location, with those living in Moyale over 10% more likely to suffer displacement as a result of drought compared to other locations, whilst those resident in South Sudan are 10% less likely to.

Table 3. Interaction models: Impacts of drought exposure on mobility for different population groups

	Dependent variable: Displacement (Binary)					
	model1	model2	model3	model4	model5	
Drought (0/1)	0.0226*** (0.0038)	0.0392*** (0.0046)	0.0418*** (0.0051)	0.0214*** (0.0037)	0.0822*** (0.0109)	
Drought x Houseowner (0/1)	0.1050*** (0.0144)					
Drought x Asset index (0-4)		0.0365*** (0.0089)				
Drought x Livestock (0/1)			0.0421*** (0.0146)			
Drought x Moyale cluster (0/1)				0.1072*** (0.0143)		
Drought x Kenya (0/1)					-0.0505*** (0.0140)	
Drought x South Sudan (0/1)					-0.1000*** (0.0114)	
Drought x Uganda (0/1)					-0.0077 (0.0140)	
Fixed-Effects:	-------------	-------------	-------------	-------------	-------------	
q_id	Yes	Yes	Yes	Yes	Yes	
______________	______	______	______	______	______	
S.E.: Clustered	by: q_id	by: q_id	by: q_id	by: q_id	by: q_id	
Observations	22,517	22,517	22,517	22,517	22,517	
R2	0.10227	0.09011	0.08805	0.10322	0.09662	
Within R2	0.03854	0.02552	0.02331	0.03956	0.0325	

Note: Fixed effects regression models. Coefficients in cells with cluster robust standard errors in parentheses. P-Values: 0 < *** < 0.01 < ** < 0.05 < * < 0.1

7.3.3. Descriptives on shocks and disruptive events

Within the survey, respondents were asked to estimate the value of the damage they suffered as a result of every shock and disruptive events. These damages were reported in local currencies and converted into equivalent US dollar value as part of the analysis to enable comparison across locations. The distribution of damages for each cluster is illustrated in Figure 16.

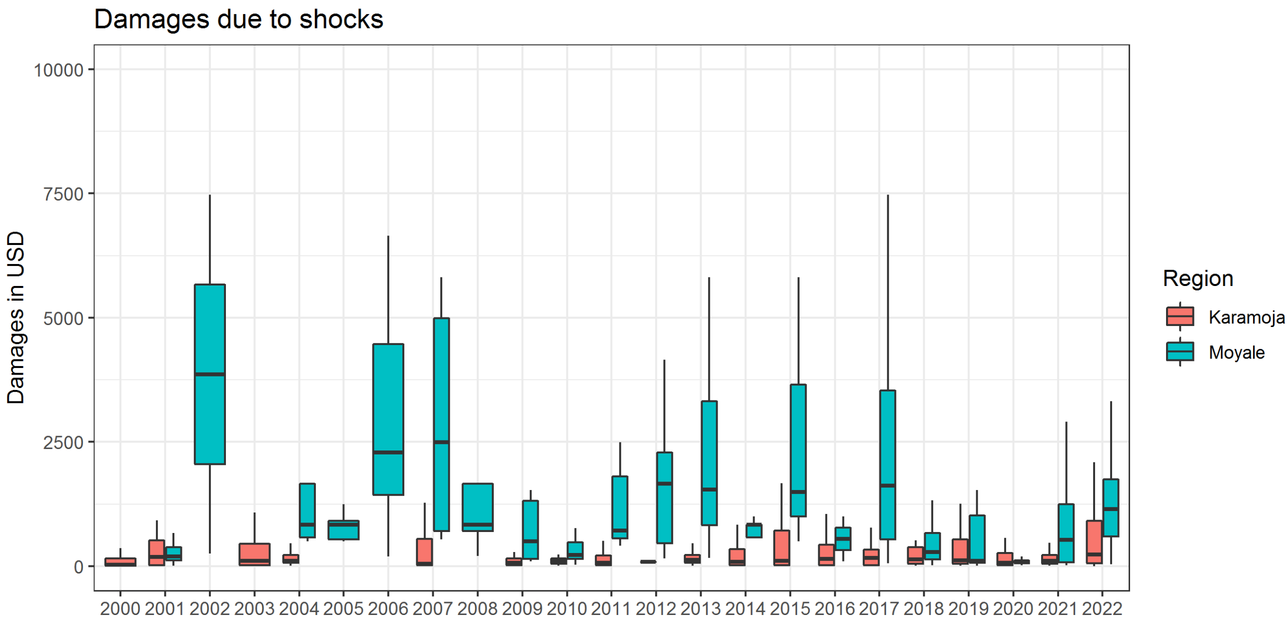


Figure 16: Reported damages due to shocks across Karamoja and Moyale clusters since 2000

An analysis of the experiences since 2010 shows that if a household records experiencing drought on average they report a $732 livelihood loss per drought event (i.e. the average household loss from 2010-2022 per year). The spread of reported damages for this period is illustrated in Figure 17.

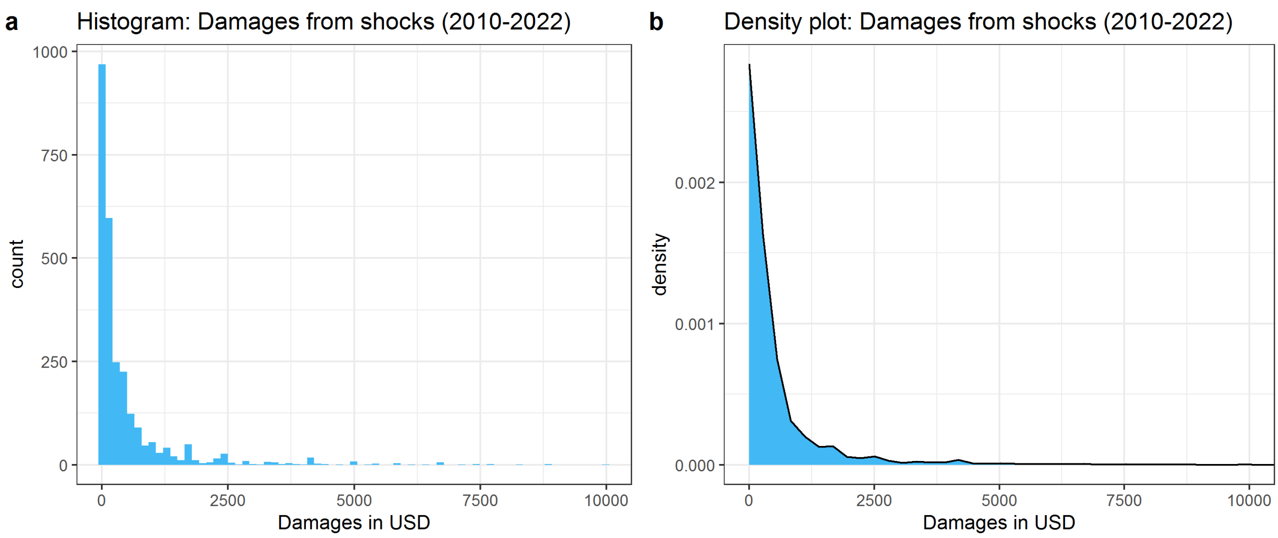


Figure 17: Spread of reported damages from shocks since 2010

The results of modelling of the impacts of different shocks on livelihood losses at the household level are outlined in Table 4. Drought and livestock disease are shown to have the greatest influence on livelihood losses – and it is noted that that rates of disease increase in times of drought.

Table 4. Models: Impacts of different shocks on livelihood losses at the household level

	Dependent variable: Livelihood losses (USD)			
	model1	model2	model3	model4
Drought	752.1*** (90.03)			
Livestock disease		724.5*** (101.9)		
Conflict			616.2*** (86.93)	
Livestock theft				632.3*** (106.6)
Fixed-Effects:	-----------------	-----------------	-----------------	-----------------
Household	Yes	Yes	Yes	Yes
___________	___________	___________	___________	___________
S.E.: Clustered	by: q_id	by: q_id	by: q_id	by: q_id
Observations	22517	22517	22517	22517
R2	0.08582	0.09265	0.09483	0.11316
Within R2	0.02092	0.02825	0.03058	0.05021

Note: Fixed effects regression models. Coefficients in cells with cluster robust standard errors in parentheses. P-Values: 0 < *** < 0.01 < ** < 0.05 < * < 0.1

7.3.4. Relationship with climate and environmental data

A number of climate and environmental data indices were analysed to assess whether a relationship between these and reported displacement, livestock loss or livelihood loss could be established.

Analysis of historic NDVI indices showed a significant trend over time (Figure 18), suggesting that there is an increase in vegetation across the region, potentially as a result of the spread of invasive species. No relationship was established, however, between NDVI and livestock loss or livelihood loss.

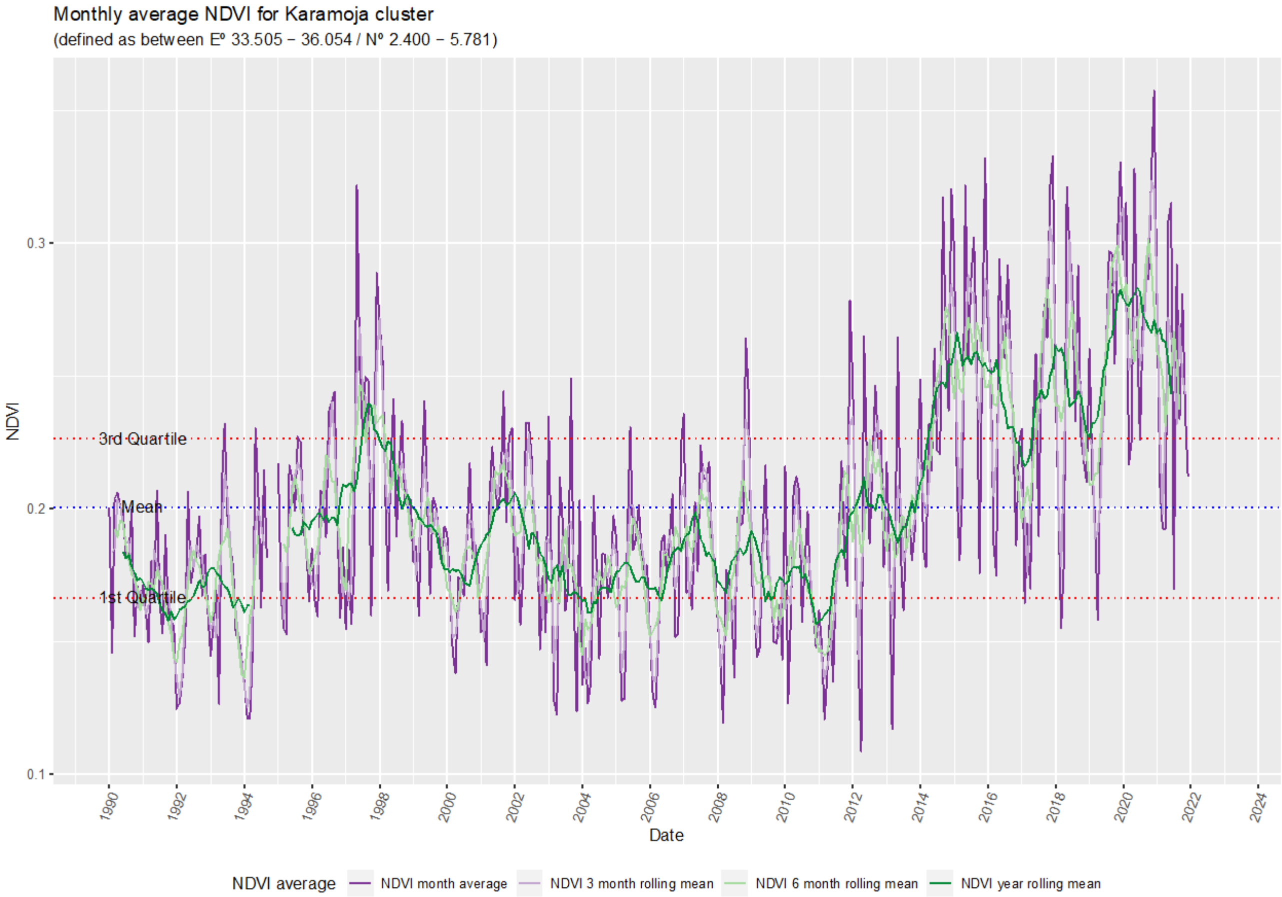


Figure 18: NDVI averages for Karamoja cluster

The modelling of objective climatic variables drawn from SPI and SPEI indices is detailed in Table 5. This shows that the only significant – albeit weak - relationship that could be found between objective measures of drought and displacement across both clusters was with annual SPI average. No clear relationship could be found between seasonal averages and displacement with either index.

Table 5. Models: Impacts of objective climatic variables on displacement

	Dependent variable: Displacement (Binary)			
	model1	model2	model3	model4
spei1_annual	0.0113*** (0.0024)			
spei1_JF		-0.0212*** (0.0026)		
spei1_MAM		0.0346*** (0.0055)		
spei1_JJAS		-0.0027 (0.0029)		

spei1_OND		-0.0135*** (0.0020)		
spi_annual			-0.0111*** (0.0043)	
spi_JF				-0.0006 (0.0013)
spi_MAM				0.0112*** (0.0017)
spi_JJAS				0.0026* (0.0016)
spi_OND				0.0044*** (0.0015)
Fixed-Effects:	-------------------	-------------------	-------------------	-------------------
Household	Yes	Yes	Yes	Yes
________________	______________	_______________	______________	_____________
S.E.: Clustered	by: q_id	by: q_id	by: q_id	by: q_id
Observations	21,538	21,538	22,517	21,538
R2	0.08184	0.09041	0.06719	0.08466
Within R2	0.0015	0.01081	0.00098	0.00456

Note: Fixed effects regression models. Coefficients in cells with cluster robust standard errors in parentheses. P-Values: 0 < *** < 0.01 < ** < 0.05 < * < 0.1

8. Conclusions

8.1 Summary of the work

This report outlines the current state of knowledge of the nexus between migration and the climate including a summary of different ways to model drought induced displacement from time series analysis through systems dynamics models, Bayesian networks to agent based models. It also outlines the collection and analysis of data on the subject of the displacement of pastoralists by drought in the IGAD region. This region has and is suffering from an unprecedented drought in the last two years and seen high levels of displacement.

Unfortunately, data for the region on pastoralist displacement is sparse with current datasets spanning a limited time period. The surveys initiated in the project for Moyale and Karamoja present a historical look at the relationships between drought as perceived by pastoralists; drought as measured by the objective measures such as SPI, SPEI and NDVI; livelihood and livestock loss and displacement.

The analyses reveal that drought as experienced by pastoralists leads to an over 10% increase in the likelihood of displacement, in the regions sampled (when controlling for conflict and livestock disease and theft). Within this figure there is considerable variability of the magnitude of this impact geographically, with some locations experiencing more than 20% displacement with self reported drought, and with the impact of droughts on displacement appearing more pronounced in Moyale than Karamoja. Interestingly settled populations show a significantly higher rate of displacement than mobile ones supporting the recognition of the resilience of pastoralist livelihoods to droughts.[50]

Interesting by contrast, the link between pastoralist reported displacement and drought as indicated by scientific measures of SPI and SPEI is weak (but significant) and no relationship was found between NDVI and displacement. Indeed there is limited coherence between the scientific measures of drought and its recorded existence from the perspective of pastoralists.

Lastly and somewhat unsurprisingly the analyses also show that livelihood loss is highly correlated with livestock loss. In terms of drought if household has reported experiencing drought they report a $732 livelihood loss per drought event (i.e. the average household loss from 2010-2022 per year). This drops to $183 with each unit decrease of SPI.

8.2 Future recommendations

Moving on from the project we suggest the following research agenda:

- There is a strong need to gather more migration and displacement data. This should include more surveys of livelihood loss and migration histories by the member states of IGAD, with the lessons learned from this project used to design an appropriate sampling strategy. There is also a need to streamline the data collection process with the use of appropriate tools such to ensure the quality of the data and the efficiency of the data collection. Importantly we feel there should be some attempt to collate all the different mobility data sets collected as well as those mentioned in Chapter 2 in one place, preferably ICPAC which has the capacity to

[50] Scoones, I. 2022. Livestock, Climate and the Politics of Resources: A primer. Transnational Institute (TNI). https://www.tni.org/en/publication/livestock-climate-and-the-politics-of-resources

combine these data with environmental data from Hazard Watch. This will involve establishing institutional relationships with such international partners as IOM, UNHCR, and IDMC, to obtain displacement and migration data at a high spatial resolution (possibly at the second administrative level) and a high temporal frequency (ideally with at least monthly mobility information). Having a longer time series dating back several years to the past represents an advantage for the statistical modelling of the hazard-mobility response relationship.

- Further work should establish the relationship between reported drought from surveys and SPI, SPEI, NDVI and TAMSAT Alert data. As stated above our research only found a week coherence between reported drought and the scientific measures of the drought hazard, e.g. for each unit decrease in SPI there was only a 5% increase in the likelihood of people reporting drought. There are a number of reasons why this discrepancy might exist. Foremost the reported incidence of drought is a product of drought hazard, hazard exposure and its impact whereas SPI, SPEI and NDVI are measures only of the hazard. Secondly the objective measures are for a larger or different area to that experienced by the pastoralists. This second question is harder to resolve due to the lack of knowledge of grazing territories.
- Clearly this report has focussed on quantitative data and there is a clear need to triangulate our nascent findings with qualitative accounts of mobility responses to drought. The addition of a qualitative approach will also allow to discover and take into account region-specific factors that influence drought-induced human mobility.
- Given the impressive Hazard Watch system at ICPAC, future work might add the descriptive statistics for Moyale and Karamoja, from the surveys of:
  - % population expected to be displaced, suffering from livestock and livelihood loss from different levels of SPI anomaly.
  - % of different cohorts of population expected to be displaced, suffering from livestock and livelihood loss from different levels of SPI anomaly.
  - % of population expected to be displaced, suffering from livestock and livelihood loss given different levels of drought intensity and duration, milk price anomaly, fodder price anomaly and conflict levels.
- There is clearly potential to use the regressions from the project in combination with forecasts of SPI to produce a forecast of displacement for Karamoja and Moyale. Further development of this could include using machine learning to further fine tune the forecasting system skill.
- The project explored the use of the IDMC or SODRD systems dynamics model (see pages 26-28 of this report) for modelling drought induced displacement. Unfortunately we were unable to parametrize the model for our two regions due to a lack of location specific data. Foremost amongst these difficulties was a lack of data on livestock numbers. Future effort in running this model would greatly advance a process understanding of displacement in this context as well as allow for real time policy testing under the specific conditions that exist at the time.

Past work using the SODRD model has focused on the following policy options (Table 5) for managing drought displacements in pastoralist areas for the corridor between Ethiopia and Somalia. Future work should not only focus on parametrising the model for the Karamoja and Moyale but include adding system components to represent water and pasture resource management activities of pastoralists and to account for invasive plant species which are thought to cause NDVI to increase over time but are of very limited nutritional value to current livestock types.

Table 5. List of policy levers included in the model (from an unpublished Final report prepared by: Khaled Gaafar and Maria Teresa Miranda by IDMC for the Danish Refugee Council. 'Status after workshop' in this table refers to work undertaken in Somalia)

Policy areas/ clusters	Explanation	Status after workshop	Policy levers
Humanitarian aid	Assistance to IDPs/ Pastoralists to aid with their daily caloric intake	Implemented before the workshop	▪ IDP monthly cash assistance per capita ▪ Pastoralist monthly cash assistance per capita ▪ IDP monthly grain assistance per capita ▪ Pastoralist monthly grain assistance per capita
Market linkages and price information	Prevent exploitation of pastoralists while destocking. Makes sure pastoralist trading margin is higher than currently is.		▪ Pastoralist livestock trading margin
Fodder production and storage	Produce more and store it for when needed. This should reduce supply gaps and improve price stability	Implemented after the workshop	▪ Fodder supply gap reduction ▪ Percentage reduction in sensitivity of fodder price to pasture pressure
Shift herd towards drought-resistant species	Shift herd towards breeds that can last longer without food/ water		▪ Percentage resistance to pasture pressure (Camels) ▪ Percentage resistance to pasture pressure (Shoats) ▪ Percentage resistance to pasture pressure (Cattle)
Water access improvement	Catch more water for use to prevent waste		

Animal health interventions	Improve access to veterinary health services to improve livestock's survival rates during drought or after disease outbreaks	Remain as a recommendation for future developments Or improvements of the model	These policy recommendations are a good place to start for any future iterations of the model as the require a shift in the focus of the model to include relevant model structure/ more data on existing model structure that allows for their implementation
Drought insurance schemes	Provide pastoralists with an insurance plan to get support if a drought occurs, in order to rebuild their herds		
Alternative livelihoods	Diversify income to sources independent of livestock		

9. Further References and Materials

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Final Report

Development of a data model and capacity development for human mobility due to slow-onset events in the IGAD Region

Dominic Kniveton, Roland Smith, Roman Hoffmann
November 2022

CONSULTING GROUP