GLOBAL DATA INSTITUTE
DISPLACEMENT TRACKING MATRIX

# BRIDGING CLIMATE CHANGE AND HUMAN MOBILITY

COLLECTIVE ANALYSIS FOR A DEEPER UNDERSTANDING OF CLIMATE MOBILITY IN THE EAST AND HORN OF AFRICA

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Cover Photo: IOM Somalia distributed hygiene kits to the drought affected communities in Dolow, Somalia. © IOM 2022/ Claudia Rosel Barrios/ Somalia

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All participants in IOM's hackathon events in London and Nairobi in October 2023 have contributed to this report through their analysis and insights. They are listed as participants and contributors at the end of the report.

Individuals who contributed to the drafting of this report include; Victor Villa, Anna Belli, Victor Korir and Benson Kenduiywo from the Alliance of Bioversity International and CIAT under CGIAR's Fragility, Conflict and Migration initiative; and Nikki Herwanger, Nando Lewis, and Angelina Travers Liebermann from the International Organization for Migration (IOM). With thanks to Yassine Kerkeni, Megan Middleton, and Ana Lucia Villagran from IOM for copy editing and formatting support. Reflections were provided by Rune Lund from CBRAIN, Guenda Sciancalepore from Snowflake, and Girmaw Abebe Tadesse from the Microsoft AI for Good Lab.

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Nairobi hackathon participants. © IOM 2023

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# LIST OF ACRONYMS

| | |
|---|---|
| **ACLED** | Armed Conflict Location and Event Dataset |
| **ABC** | The Alliance of Bioversity International and CIAT |
| **COP** | Conference of the Parties |
| **CSV** | Comma-separated values |
| **DTM** | Displacement Tracking Matrix |
| **HDX** | Humanitarian Data Exchange |
| **IOM** | International Organization for Migration |
| **LASSO Model** | Least Absolute Shrinkage and Selection Operator Model |
| **MECC** | Migration, Environment and Climate Change |
| **NGOs** | Non-Governmental Organisations |
| **OSM** | Open Street Map |
| **ODI** | Open Data Institute |
| **UN** | United Nations |
| **UNHCR** | United Nations High Commissioner for Refugees |

# EXECUTIVE SUMMARY


The International Organization for Migration (IOM) and Snowflake held a two-part hackathon in London in collaboration with University College London (UCL) (6-7 October 2023) and in Nairobi (23-26 October 2023). The hackthons presented a unique opportunity for IOM to enhance key technical processes related to data collation, compilation and analysis, with direct implications for future use of IOM's mobility data for climate mobility research.

Furthermore, the exercises yielded valuable insights into into the feasibility of using advanced analytics for climate migration research and the critical challenges in harnessing environmental and climate-induced disaster data. Issues such as spatial and temporal coverage limitations, incompatibility and incomparability among climate data sources, data interoperability constraints, and the spatial heterogeneity of climate data were identified.

The findings can shape future research using IOM's mobility data to contribute to the climate mobility knowledge base and also serve as a catalyst for improving data accessibility, ultimately enhancing the analytic potential of IOM's mobility data. This aligns with IOM's core institutional priorities and commitment to contributing to a better understanding of mobility driven by climate change and environmental degradation.


## KEY POINTS:

**1. Data Value and Decision-Making:**

- The value of data lies not merely in its collection but in the analysis it enables. Investments in enhancing data's analytic potential directly contribute to increasing its overall value.
- The hackathons served as a catalyst for understanding the barriers and enablers of interoperability between IOM's mobility data and key data sources on climate change and environmental degradation.

**2. Using Diverse Data Analysis Methods:**

- Interdisciplinary teams employed diverse analytical methods to examine IOM's data with the objective of assessing the benefits and constraints of these approaches in elucidating insights on climate mobility.
- Findings from the events were converted into recommendations for future research avenues that encompassed: machine learning, understanding human movements, intersectionality, and merging large humanitarian datasets for climate mobility analysis.

**3. Hackathon Impact:**

- During the hackathon, previously unavailable flow monitoring data was made accessible to participants with diverse skill sets and expertise for analysis.
- The hackathons demonstrated the potential of combining migration and displacement data with climate-related variables.
- Participants illustrated the barriers and facilitators to using this data for climate mobility research.
- The events were a good mechanism to test the potential of using IOM's mobility data to better understand climate mobility by bringing diverse participants and perspectives together and allowed for the exchange of domain expertise across different sectors.

# INTRODUCTION

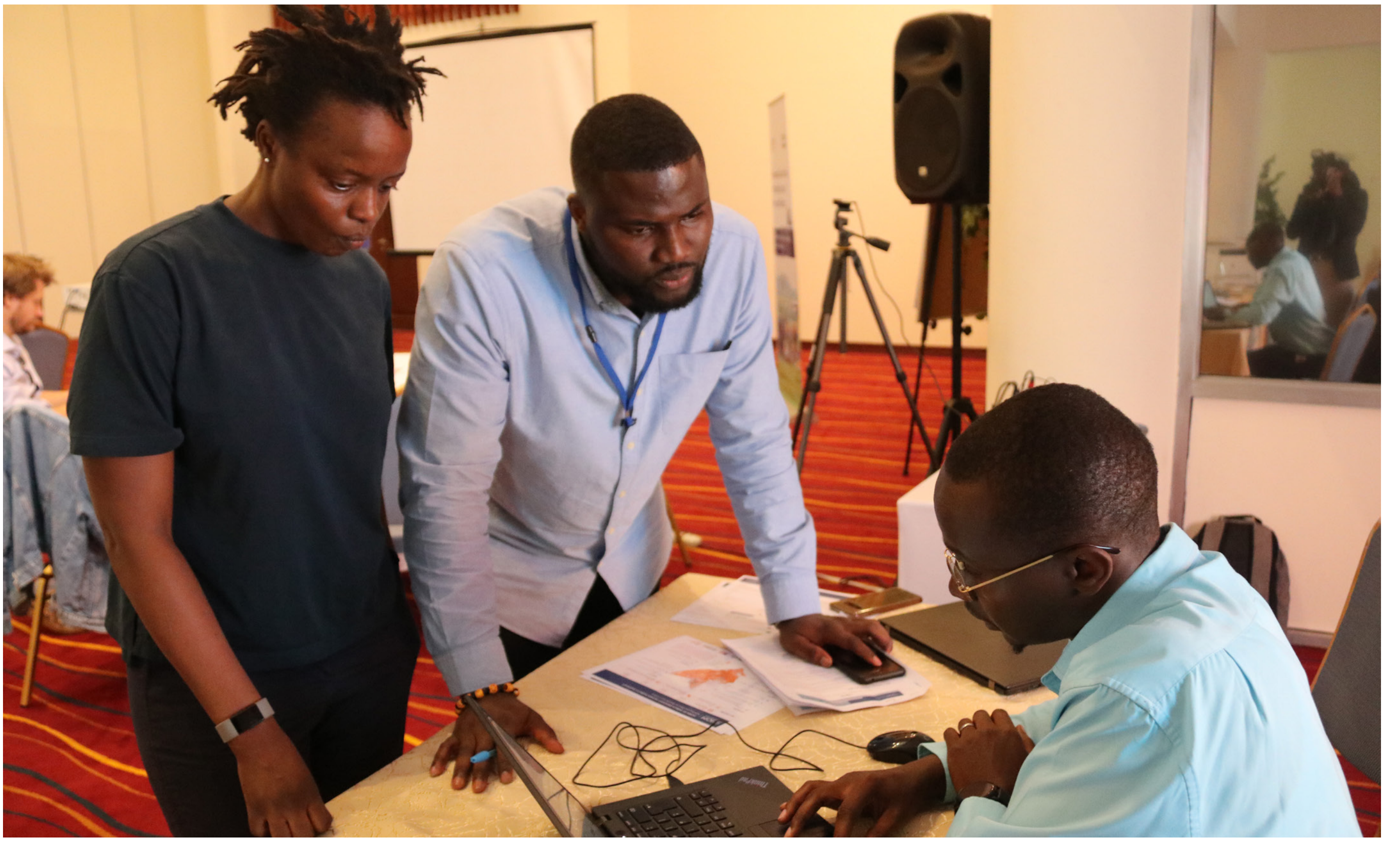
## 1.1 THE VISION FOR THE 'BRIDGING CLIMATE CHANGE AND HUMAN MOBILITY' HACKATHON

The impacts of climate and environmental change on human mobility remain a key concern for practitioners and policy makers. The International Organization for Migration (IOM) has been at the forefront of operational, research, policy and advocacy efforts, seeking to bring environmental migration to the heart of international, regional and national concerns, in collaboration with its Member States, observers and partners (IOM MECC[1]). In preparation for the United Nations Climate Change Conference (COP 28) in Dubai, United Arab Emirates in 2023, IOM partnered with Snowflake, a private sector partner that specialises in data cloud technology, to host a two-stage hackathon on climate change, environmental degradation and human mobility. Snowflake leveraged their technology and technical expertise to support IOM's contribution to the climate mobility agenda at COP28.

IOM's expertise in human mobility and its relationship to climate shocks, and data from its Displacement Tracking Matrix (DTM) global data collection programme, was paired with Snowflake's Data Cloud technology for the hackathon events. The East and Horn of Africa was selected as the geographic focus due to its complex mobility dynamics and repeated exposure to both sudden and slow onset climate shocks. This is a region in which 36.6 million people were affected by drought, 2.7 million were displaced and 5.7 million internally displaced people (IDPs) were living in affected areas by the end of 2022 (IOM, 2022a).

The overarching objectives of the event were to leverage the collective skills, expertise, and engagement of both students and professionals to brainstorm questions, challenges and approaches to understanding and analysing climate-induced migration in the region with a view to producing insights pertaining to climate-induced migration patterns. The events aimed to identify and document technical solutions that could facilitate the extensive utilization of existing data sources for future initiatives, and to develop and test approaches for combining IOM and external data sources for analysis on climate mobility in the region.

1 IOM and Migration Environment and Climate Change. For more information: https://environmentalmigration.iom.int



Technical and academic experts collaborated on analysis of IOM's mobility data. © IOM 2023

In collaboration with Snowflake and UCL, the two-part hackathon brought together participants in London (6-7 October 2023) and Nairobi (23-26 October 2023) to explore data-driven solutions and improve understanding of the complex relationship between climate change, disasters, environmental degradation, and human mobility in the East and Horn of Africa region. The London-based event engaged students across six universities in the United Kingdom while the Nairobi-based event drew from a pool of technical experts and senior academics from across the region and the globe as participants. This wide range of participants ensured a diversity of voices and perspectives in the analysis and provided a valuable opportunity to increase awareness of relevant available data sources.

The specific goals of the event were:

**OBJECTIVES**

**01** To create a proof-of-concept data repository combining IOM's data on migration flows in the region with other data sources on climate change and environmental degradation.

**02** To make this repository accessible to researchers, technical specialists, programmers, data scientists and others during the event with the aim to explore the analytic potential of the data.

**03** To explore innovative 'out-of-the-box' solutions to analysing data on human mobility in the face of climate change and environmental degradation with the help of Generative AI and alternative (including proxy) data.

Multidisciplinary teams collaborated to address critical research questions on the relationship between climate change, disasters, environmental degradation, and human mobility in the region, documenting their processes and challenges. These teams were composed of thematic experts partnered with data analysts and technical experts from data fields. This final output, based on the work done during the hackathon, highlights key findings and offers guidance on effectively using and integrating data sources to advance understanding of climate-induced human mobility. Furthermore, it explores the value added and lessons learned from interdisciplinary research initiatives for future events.

## 1.2 WHAT IS A HACKATHON ?

Hackathons are events involving teams of multi-disciplinary participants working together to solve a common problem, develop a project that meets a defined need, or build prototypes and develop proof of concepts. The events are usually competitive, taking place over a short period of time and have traditionally focused on driving innovations in the tech space, often being hosted by a company or organization working in related fields. These events can be large or small and can include participants from within a single organization or from a range of different organizations (Heller et al., 2023).

Over time, the scope of hackathons has expanded along with the topics covered by these events. While traditional hackathons harnessed the skills of computer programmers, many sectors now employ hackathon methodologies to tackle problems, drawing on skills from a wide range of participants including in education, medicine, the sciences, government, policy, and many more. The expanding use of hackathons to drive innovation across a range of fields and academic research on these events shows their value in terms of producing innovative new ideas (Heller et al., 2023). However, it is also important to note that, while hackathons have been found to drive new thinking, they seldom result in finalized 'market ready' solutions and require significant follow up to operationalize ideas which emerge during the events (Kamariotou & Kitsios, 2022).

## 1.3 THE VALUE OF A HACKATHON ON MOBILITY DRIVEN BY CLIMATE CHANGE AND ENVIRONMENTAL DEGRADATION

In addition to yielding valuable insights through analysis, the hackathon provided an opportunity for IOM to build on key technical processes linked to data sharing and analysis, with implications for future use of IOM's mobility data, particularly for its use in building the knowledge base on climate mobility.

Recent research on methods to determine the value of data suggests that their value lies in the ability of analysis produced using the data to inform decisions and actions (Coyle & Manley, 2023). From this perspective, investments in increasing the analytic potential of data also increase its value. One method of making data more analysable is to increase accessibility and facilitate use. Researchers in the field of open data ecosystems highlight the mutual benefits reaped by both data owners and those accessing open data in terms of insights and innovations and the impact thereof on decisions and actions (Runeson et al., 2021). The Open Data Institute, for example, has conducted extensive research on the use of open data – data that anyone can access, use and share – to generate income in the private sector (Open Data Means Business | The Open Data Institute, n.d.).

Much of IOM's operational displacement data are open source, in the sense that they are accessible through the DTM website and through data sharing platforms such as the Humanitarian Data Exchange. Whilst IOM's displacement data is often made publicly available due to its humanitarian mandate, data collected on flows and migration are not historically shared due to data sensitivity and a lack of existing protocols for sharing regularly. The flow data mobilized for the hackathon were not part of IOM's existing open data and analysis of the data by actors external to IOM was limited. One of the steps in the hackathon process was to identify ways of making this type of data more accessible and shareable to thereby increase its analytic potential, particularly for climate mobility researchers. In this sense, the hackathon served as a proof of concept for increasing access to these data.

In addition to accessibility and shareability, a further barrier faced when seeking to analyse data by combining different data sources is the problem of interoperability. Data interoperability describes the elements that allow for different datasets to be combined or aggregated for analysis of multiple data sources (Data Interoperability Collaborative, 2017). These can include data formatting, accessible meta data and more. For example, data that are collected about specific displacement camps in a country may not be easily combined with data on average household incomes in each district of the country, because the two data sources provide information at different geographic administrative levels. Some interoperability challenges can be overcome by normalizing the relevant variables across different data sources, (dis)aggregating variables to harmonize geographic units of observation, manual transformation, or mapping of data sources through data cleaning; however, this is a time intensive process. Obstacles to interoperability limit the usability of data, even if they are open and accessible, and thereby reduce their value and analytic potential (Kush et al., 2020).

The hackathon provided an important opportunity for analysts with a wide range of technical and thematic expertise to evaluate and document interoperability challenges when combining IOM's data with other data sources related to climate change and environmental degradation. These observations will support IOM in improving the interoperability of its data, increasing its ability to be analysable and impactful in the field of climate change and environmental degradation.

FGDG

# 2. ONGOING CHALLENGES IN ANALYSING THE IMPACT OF CLIMATE CHANGE AND ENVIRONMENTAL DEGRADATION ON HUMAN MOBILITY

# 2. ONGOING CHALLENGES IN ANALYSING THE IMPACT OF CLIMATE CHANGE AND ENVIRONMENTAL DEGRADATION ON HUMAN MOBILITY

Authored by: Victor Villa, Anna Belli, Victor Korir and Benson Kenduiywo (ABC)

Despite the growing body of literature on climate change and human mobility, significant limitations persist in terms of data quality and availability that are yet to be adequately addressed to improve quantitative research on the topic.

Climate and environmental data, despite being frequently collected and publicly available, have some inherent challenges. Firstly, the spatial and temporal coverage of some crucial environmental and disaster-related data – like up-to-date land-use/-cover data, deforestation information or flood episodes – often exhibit gaps. Therefore, crucial information on environmental factors interlinked with displacement flows and settlements is not consistently accessible for every location and time. This fragmentation in data availability and collection results in incomplete datasets, obstructing a comprehensive understanding of climate change and environmental degradation patterns. Secondly, there is a lack of compatibility and comparability among various climate data sources, contributing to inconsistencies and difficulties in integrating data for a thorough analysis. This challenge becomes particularly pronounced when examining multiple indicators that may ultimately capture similar dynamics, such as droughts and shifts in maximum temperatures, or notably, heavy rains and floods. Thirdly, adding to the complexity, the spatial heterogeneity of climate data presents a significant challenge when attempting to bridge climate data with other socio-economic datasets. As a result, the presence of multiple scales and resolutions exacerbate the difficulties in combining such information (Karpatne & Liess, 2015). These challenges in climate and environmental data pose significant obstacles to gaining a holistic understanding of climate change impacts, particularly concerning its correlation with human mobility patterns in the long term.

Conversely, human mobility data present other challenges. Firstly, the information is typically gathered focusing on flows of migrants and displaced individuals, which may not be entirely representative of the broader population. This approach makes it difficult to draw meaningful comparisons between migrants and non-migrants, hindering the assessment of specific individual-level factors contributing to these distinctions. Having representative data encompassing both migration flows and the overall population in origin areas would allow for a more accurate statistical estimation of the causality mechanism of climatic and environmental-related mobility. Secondly, the data on mobility often fail to capture instances of migration driven by environmental and climatic factors as they are rarely perceived as the main factor that triggers mobility. This limitation results in a disproportionate emphasis on more traditional reasons for migration, neglecting the underlying factors that may force and induce individuals to relocate. Therefore, mobility surveys might need to develop new strategies to capture the compounding effects of climate variability and environmental degradation on the migration decision process. Thirdly, it is difficult to obtain fully compiled datasets on human mobility. Consequently, a significant amount of information appears missing, especially regarding the intermediate destinations of migrants and displaced individuals or the granular details about their areas of origin — whether their movements are international or internal. This scarcity of comprehensive information impedes a thorough understanding of migration patterns and limits the ability to discern the nuanced factors influencing the journeys of individuals. This suggests that the traditional datasets focusing on origin-destination and push-pull factors need to incorporate more detailed information on mobility to enable the tracking of migration routes and strategies over an extended period of time, potentially unveiling the evolving climate change effects (Helbling et al., 2023). Lastly, mobility data usually vary across countries and regions, as they are collected using different surveys. This diversity in data collection methods makes it challenging to draw meaningful comparison across time and geographical areas.

The aforementioned data limitations underscore some of the challenges associated with conducting analyses on climate-driven mobility. Beyond specific data gaps, research in the field needs to adopt a more differentiated, integrated and generalized approach (Oakes et al., 2023). In terms of differentiation, several research gaps persist, particularly when examining vulnerable groups, such as the youth, older people, or marginalized communities. Research differentiation also falls short geographically, with certain areas still being understudied compared to others when exploring climate mobility (Ibid). Another challenge in climate mobility research concerns the need for embracing multidisciplinary and multi-sectoral approaches. This implies that qualitative and quantitative approaches should be integrated to answer the complex research questions around climate-driven mobility. However, achieving an integrated approach may be difficult if climate and migration data lack complete accuracy and reliability for further validation or integration with qualitative approaches. Along this line, another important challenge concerns the validation of existing migration datasets. This is essential not only to ascertain the information contained in the data and identify relevant indices that can be used to model the relationship between climate change, environmental degradation and human mobility, but also for generalization (Helbling et al., 2023). Indeed, such validation needs to ensure the external validity of these sources. So far, existing findings cannot be generalized to other contexts outside the analysed sample. Thus, the representativity of the data needs to be proven through comparison with external sources and through engaging official actors (Andrade, 2018).

Addressing these data and methodological challenges is crucial for advancing research and formulating effective policies that account for the intricate relationship between climate change and migration. So far, research has contributed to a better understanding of the intertwined relationship between climate change and mobility. There is indeed a growing consensus that climate variability and extreme weather events serve as drivers of migration and displacement, especially within the context of rural livelihoods and dependencies on natural resources (Hoffmann et al., 2020; van der Land et al., 2018). Despite these efforts, several barriers to produce impactful climate mobility research are yet to be overcome. Moving forward, a united effort is imperative, necessitating collaboration among researchers, policymakers, and data providers to not only enhance data quality but also to cultivate interdisciplinary collaboration. Overcoming these challenges collectively will pave the way for more profound insights into the dynamics between climate change and human mobility, facilitating informed decision-making and the development of robust policies in the face of environmental challenges.

# 3. FINDINGS

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# 3. FINDINGS

This section presents the key takeaways from the group research that took place over the course of both hackathon events. As all analysis done during the event was exploratory, the findings have been converted into recommendations for future research avenues.

Table 1: Outline of datasets used across all teams

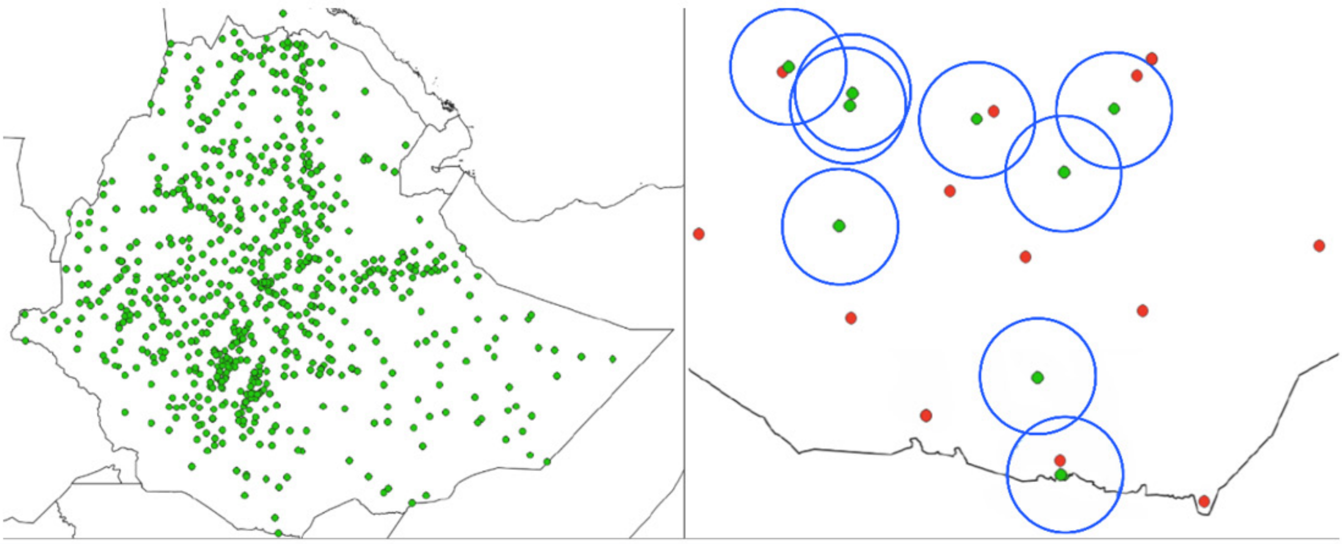
| Data Providers-Source/Categories | Global Data Lab | Consultative Group on International Agricultural Research (CGIAR) | Socioeconomic Data and Applications Center (SEDAC) | Climatic Research Unit (CRU) | Earth System Science Data (ESSD) | IOM-DTM | Nature | ZENODO | Centre d'Études Prospectives et d'Informations Internationales (CEPII) | Armed Conflict Location & Event Data Project (ACLED) | Global Drought Observatory (GDO) JRC | mixedmigration (MMC) | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate | | 6 | | 7 | | | | | | | | | 13 |
| Conflicts | | | | | | | | | | 1 | | | 1 |
| Food Security | | | 1 | | | | | | | | | | 1 |
| Hazard and Risk | | 10 | 6 | 1 | | | | | | | 1 | | 18 |
| Land use | | | | | 4 | | | | | | | | 4 |
| Migration/Displacement | | | | | | 2 | | 1 | | | | 1 | 4 |
| Socio-Economic | 17 | | 5 | | | | 2 | 2 | 1 | | | | 27 |
| 7 | 17 | 16 | 12 | 8 | 4 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 68 |

## 3.1 MACHINE LEARNING:

*Nairobi Team 1 (Teo Ficcarelly, Daniel Ibañez, Markus Rudolf, Guenda Sciancalepore, Victor Villa)*

Hackathon participants from Team 1 in Nairobi explored LASSO, the Least Absolute Shrinkage and Selection Operator machine learning approaches, to link different large data sets with the aim to explore the scope for machine learning to quickly identify relationships for further investigation.

Figure 1: Nairobi Team 1 – Departure locations within Ethiopia (Left) and example of departure locations captured through DTM datasets within 20km of conflict events captured through ACLED conflict data (Right)

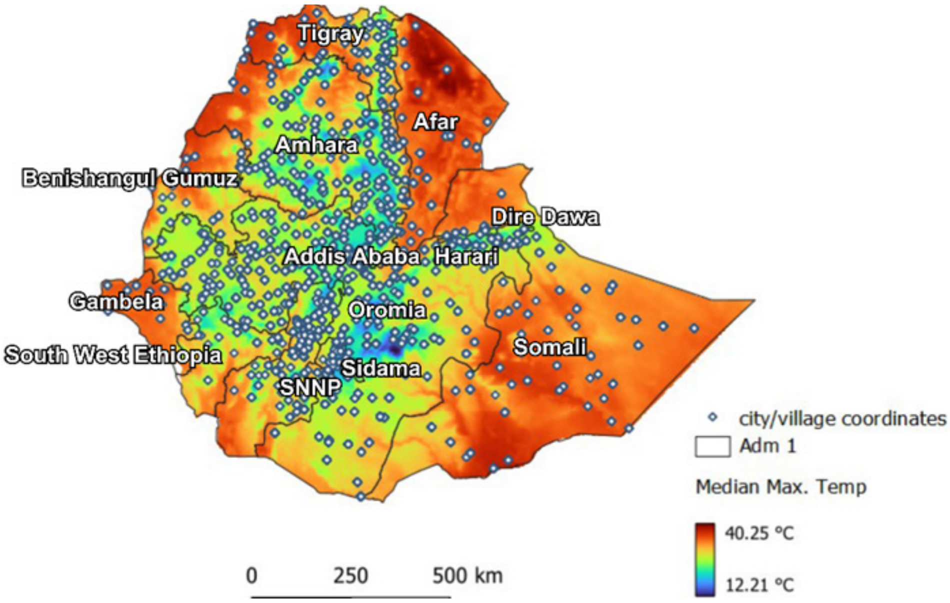


*Note: This map is for illustration purposes only. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the International Organization for Migration*

IOM's Flow Monitoring Survey (FMS) data used for this event did not include the GPS coordinates for the areas people were departing from. To obtain these coordinates, a geo-coding exercise was conducted. This exercise involved using Google Maps servers to project the descriptive answers (administrative level 1,2, and 3) provided by individuals about their original locations. The resulting coordinates were then used to create a more detailed association between climatic and conflict data with the original FMS. An example of this work can be seen in the map above.

A LASSO model is a machine learning approach that was predominantly developed for analysis of linear relationships but can be applied to other model types. This permitted the team that produced this analysis to consider a substantially larger volume of variables and relationships than preliminary regression models based on literature and general knowledge. The LASSO model was used as a "feature selection" tool, to identify possible hidden relationships within the variables contained in the dataset. This team demonstrated that in the space of four days, a team ranging from data scientists to anthropologists could collate relevant climate and socio-economic data with humanitarian human mobility data into a format that could be analysed using machine learning approaches.

Figure 2: Nairobi Team 1 – Departure locations within Ethiopia captured through DTM datasets, overlayed on median maximum temperature for the period 1990-2020 (Terraclimate)

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The quantitative literature researching relationships between climate and environmental change and human mobility has developed considerably over the past decades. Improvements in the quality, quantity and specificity of available data combined with the continuous development of more sophisticated analytical techniques and software have fostered a proliferation of publications. These studies have predominantly focussed on precipitation or temperature as examples of climate impacts and generally attempted to fit linear models to investigate these relationships (Hoffmann et al 2021). There are increased calls to use variables that are directly relevant to communities such as floods or crop failure rather than potentially abstract values such as temperature (Beyer et al 2023). One of the research teams in the Nairobi hackathon used the Palmer Drought Severity Index (PDSI) in their analysis. This uses readily available temperature and precipitation data to estimate relative dryness. It is a standardized index that generally spans -10 (dry) to +10 (wet) (NCAR, 2023). In using a variable that had a more tangible relation to communities they were better able to relate their analysis to important demographic characteristics of communities and their responses.

Beyond the quality of the variables representing climate and environmental change, there are increased calls to use more sophisticated analytical techniques. Researchers have highlighted that linear models are not able to capture the complex patterns of human mobility linked to climate change, instead suggesting that machine learning approaches are essential (Beyer et al 2023; Ronco et al 2023). Machine learning approaches help the researcher to uncover relationships in the data. Standard regression-based models are sometimes limited by the imagination and contextual knowledge of the researcher: if one does not deliberately investigate a potential relationship, they are very unlikely to uncover it. It would be unrealistic to require a quantitative researcher to understand all the cultural and contextual intricacies of the locations they are analysing.

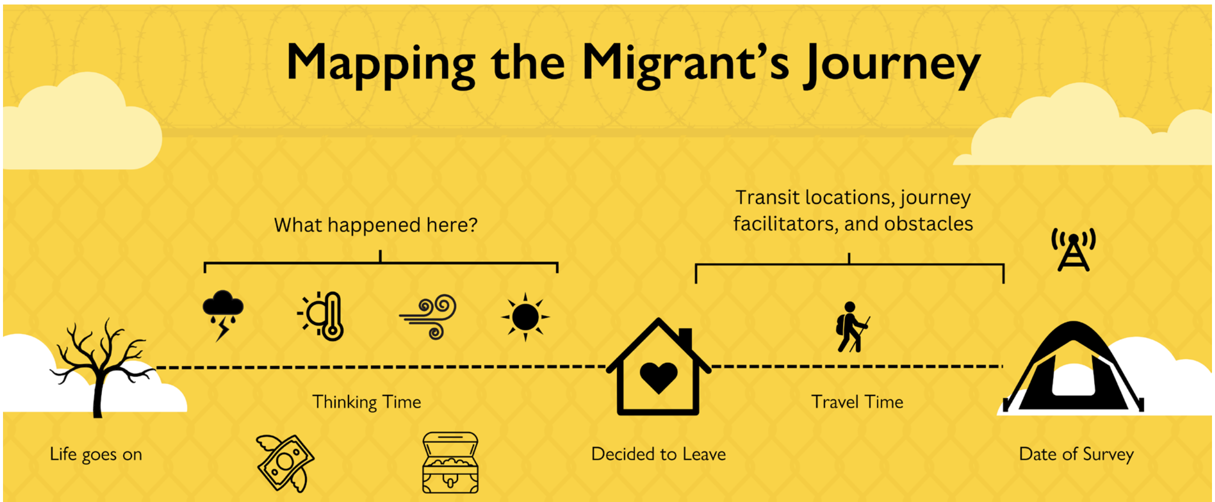
Machine learning approaches iterate based on the data being analysed and very quickly identify statistical relationships that are present. Potential positives of this approach are that contextual and cultural factors that are unknown to the researcher may appear in the data. As with all research, unanticipated findings must be critically assessed; it is crucial to understand what a relationship means in reality. This is where the hackathon concept is potentially uniquely positioned to support these analyses as teams brought together wide varieties of expertise and, perhaps most importantly, connected highly technical skillsets with in-depth qualitative experience and understanding of the contexts and phenomena being investigated.

## 3.2 UNDERSTANDING JOURNEYS:

*Nairobi Team 2 (Aneeshaa Choudhury, Victor Korir, Khellia Munezero, Fawad Qureshi, Olive Wangui) and Nairobi Team 4 (Maxwell Adero, Rehema Batti, Assad Asil Companioni, Anton Huck, Martin Brown Munene, Elisabetta Pietrostefani)*

There can be a tendency to think of human mobility as A and B, origin and destination, but this risks missing crucial temporal aspects of when a journey begins in someone's mind and in reality, and crucial spatial aspects of the physical route they take from A to B. Teams in the Nairobi event hypothesized methods through which two components of the journey, how long it takes and the physical route that is used, could be better explored.

Figure 3: Nairobi Team 2 – Theoretical model of the journey; thinking time and travel time.

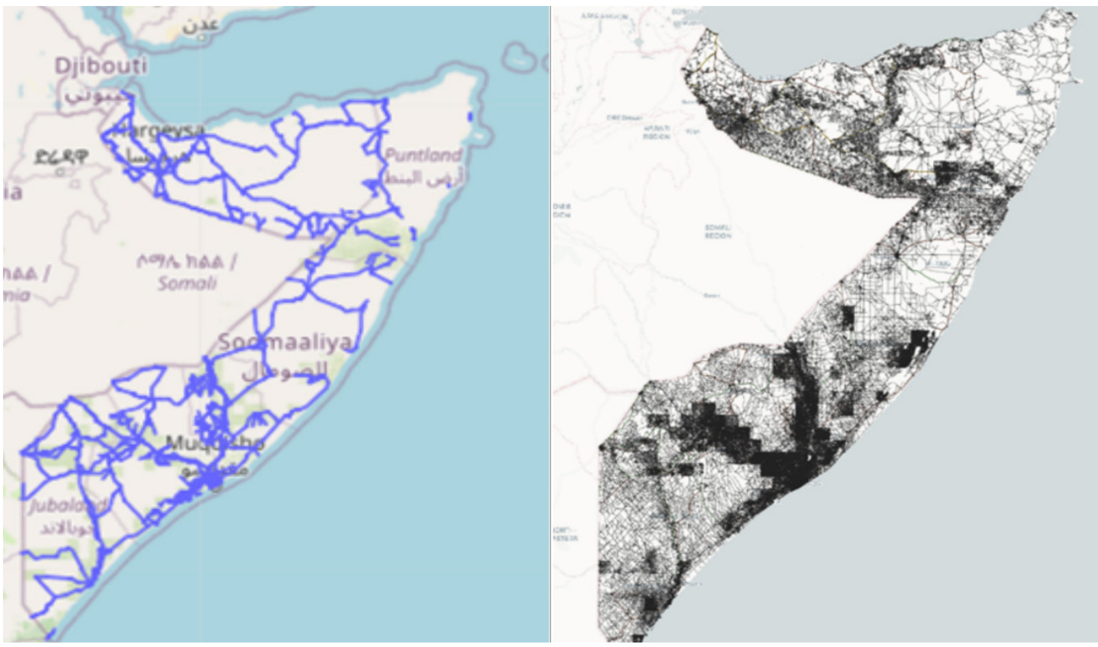



Note: "thinking time" refers to the pre-migration contemplation period during which individuals or families deliberate on the decision to leave their current environment. This phase encompasses the assessment of personal, climate and environmental, economic, and social factors against potential opportunities and risks in a new location.

The length of the journey, beyond its impact on those on the move, is a crucial consideration for any quantitative analysis to understand the link between human mobility, climate change and environmental degradation. When linking factors in an origin area with arrival in a destination area, understanding the time lags can help in knowing which climatic factors were relevant in the movement of an individual or community. For example, flooding could destroy both homes and road networks or render rivers impassable while strong winds or wildfires could destroy homes but leave roads and rivers navigable, meaning that there may be differences in the journey times of those displaced by different events. If factors from only the previous two months are included in the model but the target populations actually left their home three months ago, then the dataset would not be representative of the conditions that the individual faced. More accurate data on travel times could improve origin-destination analysis and could help with pre-positioning and delivery of stocks for humanitarian assistance to both transit and destination locations likely to receive displaced populations due to various hazard events. The data gap on duration of journeys persists for several reasons. Primarily, operational humanitarian data focuses on the here and now, asking questions relevant for the provision of immediate assistance. Additionally, journey times are very particular to each individual/household and so cannot be accurately collected at key informant level used in much humanitarian data collection. Even at the individual level, the 'journey time' and the 'thinking time' are difficult to differentiate. Nairobi Team 2 emphasised the relevance of thinking times and journey times in their theoretical framework. In their exploration of data sources which could support analysis of journey times, they suggested telecommunications data as a potentially useful option. While ethical concerns over the use of such personal data remain, the benefits of analysing the movements of mobile phones could also span work on identifying where mobile populations are most at risk of going missing.

Nairobi Team 4 also highlighted the potential of telecommunications data for better understanding the routes that are taken. Team 4 emphasised the value of understanding routes in improving humanitarian assistance to people on the move as well as predictions of where individuals are likely to move to in response to different hazards and the availability of roads, rivers and other paths. Using Somalia as a case study, Team 4 included two relevant data sources for understanding routes. Firstly, road networks for the whole of Somalia were used from Open Street Map (OSM). The accuracy of OSM in Somalia benefits from the substantial mapping contributions of local communities and NGOs, meaning data are also available on secondary and tertiary roads. The density of the road network meant that multiple potential routes could be identified for each origin-destination pair in the data. Secondly, Team 4 suggested telecommunications data, particularly network towers, as another data source to help triangulate their analysis. As the data on locations of mobile phones is understandably unavailable, Team 4 used public data on the location and range of phone towers. Simulations of mobile phone data were then created to demonstrate what could potentially be researched if the real-world data were to be shared. Team 4 demonstrated that it is possible to identify a range of most-likely routes using road network data, and that with access to real mobile phone data, it would be possible to match the two sources to understand journeys and journey times in locations where coverage is high.

Figure 4: Nairobi Team 4 – Somalia real road network from Open Street Map (Left) and plausible mobility routes (Right)




*Note: This map is for illustration purposes only. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the International Organization for Migration*

## 3.3 INTERSECTIONALITY:

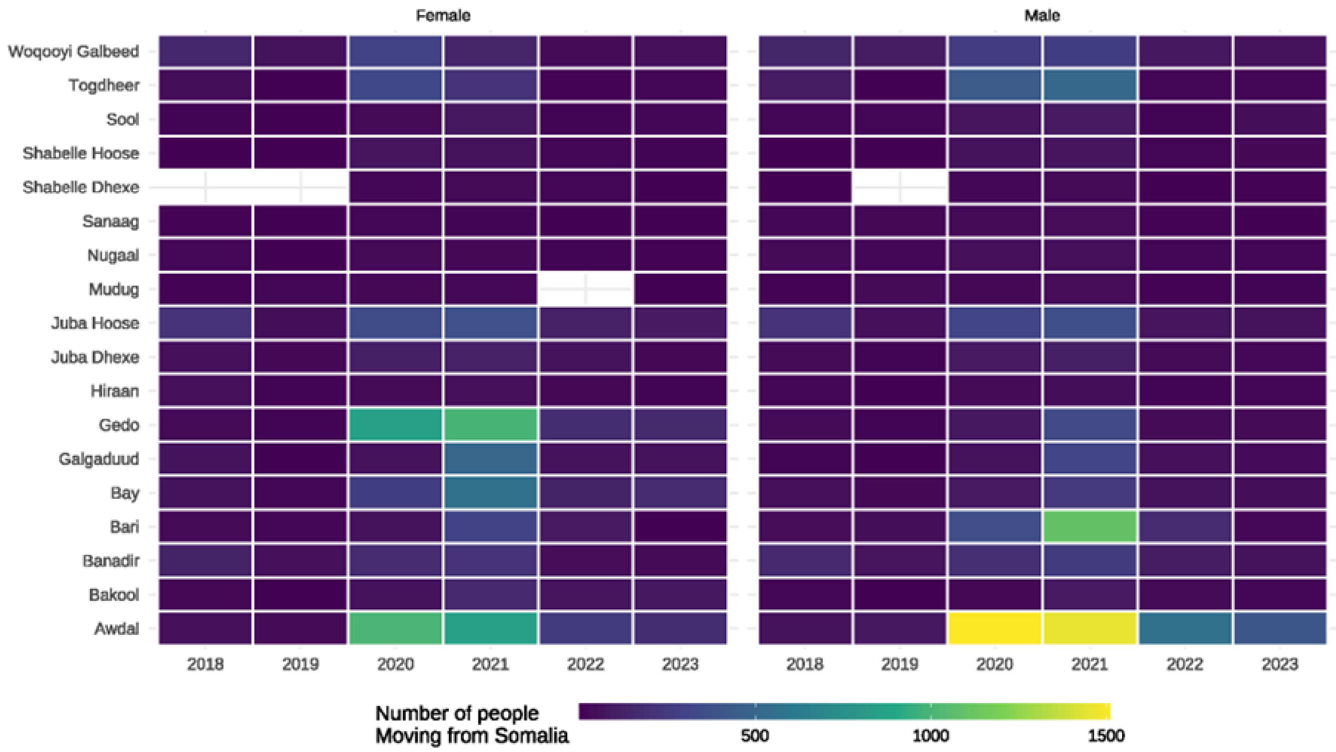
*Nairobi Team 5 (Anna Belli, Dan Hunt, Francisco Rowe, Oluwatosin Orenaike, Rodas Yeheyes) and London Team 5 (Giulia Brutti, Nowsha Farha, Peniel Adanna Ibe, Denisa Ameilia Tami, Chen Yunxi Wynsey)*

Different people respond to the same events in different ways. Understanding this diversity in response is crucial for developing an understanding of the patterns of mobility related to climate and environmental change. In practice, it is difficult to account at the micro level for the multilayered differences between individuals. However, current macro level practices that often count numbers of individuals with no distinction between them miss the nuance in the data. Multiple teams at the hackathon suggested 'meso' level approaches that investigated the intersections of different groups of individuals. There is previous quantitative research supporting such approaches, demonstrating that demographic factors impact who moves, with relationships identified, for example, for race and economic status (Mastrorillo et al. 2016) and age and education level (Bohra-Mishra et al 2017). Previous qualitative research and case studies also demonstrate the importance of demographic differences. For example, communities affected by drought in Somalia are more likely to see women and children displaced while men remain behind to protect property IOM, 2022b).

Table 2: Indicators from IOM DTM Flow Monitoring Surveys used for intersectional analysis

| Question | Response options |
|---|---|
| What is this person's sex? | Female; Male; Don't know/Don't want to answer |
| How old are you (in years)? | Numeric |
| What is your current marital status? | Single/Never Married; Married; Separated; Divorced; Widowed; Signed contract/ Consensual Union/ Domestic Partner; Don't know/ No answer |
| What is your highest level of completed education? | Includes: Primary; Lower secondary education; Upper secondary education; Bachelor's or equivalent level |
| What is your current employment status? | Includes: Employed; Unemployed and looking for a job; Student |
| What is the main profession/occupation (i.e. the one that brings more money) of your current or most recent job? | Includes: Manager; Professional; Technician; Skilled agricultural, forestry and fishery worker; Elementary occupation |
| Have you been forcibly displaced in your own country? | Yes, No; Don't know/ No Answer |

Figure 5: Nairobi Team 5 – Somalia responses by year, state of departure and sex




Nairobi Team 5 focused on both the contextual level and individual level factors that could influence human mobility related to climate change. At the contextual level, the variable was drought, and at the individual level, variables were sex, marital status, education, employment and previous displacement. This focus on both the external influences affecting individuals and the internal characteristics influencing individuals' responses to these factors was deemed crucial to better understand how climate change might impact human mobility. Using regression-based models, Nairobi Team 5 observed significant differences across all demographic factors. Given the time constraints of the hackathon, more control and other relevant variables are needed to fully contextualise the findings, and more time was needed to delve further into the intersections of these sub-groups. Nonetheless, their preliminary findings highlight the importance of including information about individuals themselves in any analysis of their mobility patterns. London Team 5 took a similar approach, also finding that demographic characteristics were significantly related to mobility. Both these teams support the findings and suggestions from previous research which posit that as certain groups of people do not all react the same way to the same contextual factors, we must focus on why they might be reacting in different ways.

## 3.4 USING AND MERGING LARGE HUMANITARIAN DATASETS FOR CLIMATE MOBILITY ANALYSIS:

*All Teams in London and Nairobi*

The volume of research conducted to date on human mobility related to climate change demonstrates the importance of this topic and the interest in improving understanding of these relationships. These studies have mostly used mobility data from surveys conducted by the researchers or other academics (e.g. Williams & Gray 2020), surveys conducted by governments or national statistical offices (e.g. Bohra-Mishra et al 2017) or global level datasets on mobility (e.g. Ronco et al 2023). Data collected for humanitarian response to displacement and mobility is largely absent from this previous research. This is despite the enormous volume of humanitarian data collection related to human mobility from actors including IOM, the United Nations High Commissioner for Refugees (UNHCR) and REACH initiatives. For example, IOM's DTM conducts over 100,000 surveys annually and the data UNHCR collects for its camp and settlement management purposes contains potentially relevant data on hundreds of thousands of individuals. Humanitarian data are collected to support humanitarian response while research is often done with specifically developed datasets to understand the phenomenon of interest.

Humanitarian datasets mainly focus on addressing the immediate needs of displaced persons and the actors providing assistance. Other datasets focus on specific information needs requested by humanitarian and government partners, for example the Flow Monitoring data used in several of the hackathon outputs which aims to derive quantitative estimates of the flow of individuals through specific locations and to collect information about the profiles, intentions and needs of the people moving. As a result, these datasets are often not framed or formatted as neatly as researchers would like for conducting their analyses. This does not detract from the fact that the DTM website currently hosts over 2,000 publicly available datasets. The data preparation and consolidation work included the use of different formats such as tabular (CSV), image-based (raster), and geospatial (shapefile). Notable transformations involved converting raster and vector data to CSV or database format, aggregating data to the administrative division 1 level for easier analysis, and maintaining pixel-level data for users who prefer a different approach. Common challenges included: the need to standardize administrative divisions and names/codes across sources; temporal changes in geographical boundaries and names; inconsistencies and or temporal changes in variables and missing values which could be crucial for analysis. All datasets used for the hackathon were open source to promote reproducibility and participants were also encouraged to integrate additional pertinent datasets based on their specific requirements.

The hackathons in London and Nairobi have demonstrated that it is possible to use data collected for humanitarian purposes to inform analyses of climate mobility. It is possible to merge these datasets with relevant climate and environmental factors. It is also possible to use sophisticated analytical techniques on the resulting datasets. Hopefully these hackathons can open the potential of humanitarian data for future use by researchers, contribute to improved understanding of climate change and human mobility, and ultimately better support the individuals and communities most impacted by climate change.

# 4. REFLECTIONS AND CONCLUSIONS

# 4.1 REFLECTIONS

Panellists and participants were given the opportunity to reflect on the event, the future of private and public sector partnerships in this space, the value of interdisciplinary research, and how the research could link to their own work on climate change, environmental degradation and human mobility.

> Based on my impressions of the event, which was my first hackathon, I think interdisciplinary approaches are relevant to help us reach solutions for complex problems. It is interesting to see what individuals are able to create in a few days.
>
> Rune Lund - CBRAIN

CBRAIN

Based on my impressions of the event, which was my first hackathon, I think interdisciplinary approaches are relevant to help us reach solutions for complex problems. It is interesting to see what individuals are able to create in a few days. As a business developer working on designing specific solutions for clients, from my understanding, the outputs and the outcomes were not so surprising, but give an idea of what is possible. If participants have more time, they could do a lot more than what was possible for the team during those few days.

I work as regional manager for CBRAIN in East Africa, where we specialize in the fast-tracking digitization primarily for the public sector. In addition, we are specialists in E-governance and implementing technological solutions for paperless ministries, and government agencies along with solutions for grant management, inspections, and licensing. CBRAIN also works on the integration of data to ensure that it is all stored in one place and can be efficiently used for the business processes of organisations, government ministries, and agencies that work towards solutions to climate change and environmental degradation challenges.

We call ourselves the 'process company' because we always say process is first, technology and data second. This is because we strive for the data to support the processes, rather than spending a lot of time building many data museums. Instead, we prioritize starting with what problem we need to solve, how we're going to solve it and how data are going to support us solving our problem. We work with clients to define their problems and sometimes they already have a clear idea of what the problem is, other times they need help in understanding the problem. This is where academia and thematic expertise can be hugely helpful, in helping us to better understand some of the problems our clients are facing as well as sharing best practices. This is one area where actors in the public and private sector can work together.

In relation to implementation and use of data and digital systems to support work on environmental sustainability, one example of this is the policy dialogue between the Danish Government and the Kenyan Government focusing on the implementation of sustainable waste management policies through the preparation of guidelines and regulations in Kenya. The Danish Government has been working for at least two years alongside the Kenyan Government in preparing a template for environmental auditing in Kenya, which is very good work. We have used those templates to digitize similar workflows with the Environmental Protection Agency. Digitization, involving turning paperwork and policies into efficient digital processes, is key to implementation; without it these policies may not take effect in the real world. However, considerations of digitization are best actioned early in the process. Clients often want to make further changes once they see what the possibilities are when working digitally but the greatest benefits come from planning for digitization early on.

My point here is to integrate digitization earlier in the process of creating policies, guidelines, and regulations. Without considering digitization at the start of your project, by the end if you want to do complicated analyses, your data systems will not be able to consolidate the data in the way that you need. The problem is there is often very little interest at the start of a project to integrate data systems or the database structure as it is something that's quite technical. One way to get around this is to pilot solutions and show end users what is possible with digital tools, to help them better understand their needs and how to configure tools and processes to meet those needs from the start of projects.

Knowledge sharing is key to make better use of expertise and resources across different industries and to tackle challenges such as climate change and the impacts of climate mobility. Knowledge sharing that relates to academia, experts, and implementation-oriented actors often involves digitalization. Implementation-oriented actors, like CBRIAN, step in when, for example, a political decision has been made, all the paperwork is done, the regulations have been prepared and the guidelines have been finalized. They act to close the time gap from political decision to implementation and identify what concrete digital tools exist out there to support the implementation of political decisions taken. The key, which also involves cooperation with the private sector, could be collaboration between actors that can develop solutions to make abstract things become reality.

> My key impressions from the event regarding the potential of interdisciplinary approaches to help us reach solutions for complex challenges such as climate-driven mobility revolve around having different voices and backgrounds around a table to discuss these nuanced problems. Everybody has their own experience and knowledge of the domain, which is incredibly important for a discussion such as this one.
>
> Guenda Sciancalepore – Snowflake

snowflake®

My key impressions from the event regarding the potential of interdisciplinary approaches to help us reach solutions for complex challenges such as climate-driven mobility revolve around having different voices and backgrounds around a table to discuss these nuanced problems. Everybody has their own experience and knowledge of the domain, which is incredibly important for a discussion such as this one. When you talk about migration and climate change, it's something that can influence or change someone's life. So, it's important not only to have a representation of this diversity at the table, but also to allow them to be in an environment where they can be free to share and express ideas and opinions. This helps in finding possible biases in the process.

As an actor in the tech space, in my work I try to stay up to date with the state-of-the-art technology that could shape solutions to challenges associated with climate change and environmental degradation. Every technology is a powerful tool, such as a brush for a painter, and it's important to enable whoever wants to use it so that it can help shape innovative or life-changing solutions. For this reason, guiding developers or data scientists in how the tools work makes it easier for them to use them and to focus on what they do best: developing a solution and bringing their domain knowledge regarding the problem they want to solve.

In terms of the future of collaboration between those working in the tech space, academia and actors such as the UN organizations/agencies and governments on this issue, I cannot stress enough how important it is to maintain a connection and an open channel for collaboration. As previously stated, this is crucial to facilitate the development of solutions. Tech companies bring to the table the tools to change real-life problems impacting millions of people. Tech needs to be at service of others in a way that doesn't discriminate. Tech companies have the knowledge of what is the latest on the market, but academia and actors such as the UN/governments are the ones working with real-life problems and that can know where the technology can really impact people and make their life better.

Events such as hackathons help make better use of expertise and resources across different industries to tackle these challenges, but also create situations in which you can let ideas and knowledge flow in a safe environment, which is always valuable. Diversity is the key in my opinion to really understand these kinds of challenges and have situations in which you can freely share, and every voice can bring the conversation to the next level, closer to the solution.

> For me, the key takeaway from the event was the openness of IOM and of course the people in it, to understand the reality in their space. Sometimes when I talk to people in different organizations, they assume that the capacity and resources are there to achieve what they want without first practically evaluating this.
>
> Girmaw Abebe Tadesse – Microsoft AI for Good Lab

Microsoft

For me, the key takeaway from the event was the openness of IOM and of course the people in it, to understand the reality in their space. Sometimes when I talk to people in different organizations, they assume that the capacity and resources are there to achieve what they want without first practically evaluating this. For that matter, I think it's the right step to have a hackathon to bring in diverse participants and perspectives. Now IOM knows where it stands from a resource perspective and planning for the future will be much easier. Exercises like this are also a good validation mechanism.

It is important to acknowledge how challenging problems around climate change and environmental degradation are, and importantly, how we should all join forces to solve these problems. When you consider climate change and sustainability, it's clearly a primary concern. We already recognize that the Global South, including Africa, will be disproportionately negatively impacted by climate change compared to the emissions it generates. Given the complexity of the problems, finding the right collaborators is key as no one can reach a solution alone. The earlier we understand that we need to have diverse perspectives and expertise, not even to solve the problem, but just to clearly understand the problem in the first place, the better off we will be.

In short, the first step is understanding the resources at your disposal. That's what I mean by understanding the problem and understanding clearly what you're trying to solve. The next step is trying to get collaborators with domain expert knowledge and with different perspectives, including policy makers. Finally, impact is also key. We don't just solve problems for the sake of solving them – we want the solutions to have an impact and, therefore, validating that impact is critical.

The Microsoft AI for Good Lab team in Nairobi focuses on geospatial machine learning. This involves using satellite imagery and other complementary data sources to understand fundamental problems in climate change and sustainability. In simpler terms, food and water security, conservation, and global health and energy are some of our focus areas. We also recently created the Africa AI Innovation Council which has attracted other notable institutions like the African Development Bank, Africa Climate Foundation and Africa is Capacity. Currently we are working on several food security projects where we have tried to use satellite imagery to deal with conflict between wildlife conservation efforts and local farmers, malnutrition in children, wildfires and more. We are not working on this alone. We have many local partners including the Kenyan Space Agency, Kenya Wildlife Trust, Ministry of Agriculture, Ministry of Health, as well as other global institutions.

To best use the expertise and resources across different industries we must recognize that everyone has different capabilities and interests. A key step will be to understand what each industry can offer. Some actors, like Microsoft AI for Good, provide open-source resources that can be used by the wider community, without formal partnerships. Some industries will work pro-bono, while others have different ways of working. Understanding these aspects, as well as the limitations of different actors, is key to making best use of the expertise available across sectors.

Understanding different cultures of practice and organizational cultures is also very important. The reality is that no one actor has a perfect understanding, even regarding their area of expertise. For example, I have been doing AI research since my master's thesis in 2012, but there are still a lot of things I don't know, because even today, hundreds if not thousands of new methods papers are published in the field. Keeping up with the rate of progress is a challenge in every field. Realizing that we have a better picture of the whole when we share expertise and knowledge is vital. We learn from each other through collaboration, in workshops, in conferences, and in hackathons. These opportunities to work together are very important. Everyone has a limitation – that is the reality of the technologies and the time we are in. Tapping into the domain expertise across different sectors is key to finding solutions to the big problems of our time.

## 4.2 CONCLUSION

During two events held over multiple days in London and Nairobi, multidisciplinary research teams collaborated to address critical research questions on the relationship between climate change, disasters, environmental degradation, and human mobility in the East and Horn of Africa, documenting their processes and challenges. These teams were composed of students, thematic experts, data analysts, and technical experts from data fields. This interdisciplinary research event yielded valuable merged datasets and exploratory analyses that tested the strengths and weaknesses of the different data sources. Future events will build on the lessons learned from this one and further refine the scope of the research. The involvement of technical data teams in defining the subject matter, research questions and thematic areas covered for future events will be crucial in building up the exploratory work done through this event into solid research.

## 4.3 KEY RECOMMENDATIONS

These recommendations outline some key areas where IOM's mobility data can be further leveraged to advance climate mobility research. Further mobilizing data towards delivering lifesaving assistance, establishing durable solutions for forcibly displaced people, and facilitating regular migration pathways will contribute to a more resilient and sustainable future in the face of climate induced migration.

**1. Leverage Collaborative Data Analysis:** The findings from the IOM and Snowflake Hackathons underscore the importance of collaborative, inter-disciplinary data analysis. To advance climate mobility research, future studies should build upon this foundation by fostering collaboration between experts from diverse fields.

**2. Enhance Technical Processes:** The hackathons provided a unique opportunity for the International Organization for Migration (IOM) to enhance key technical processes related to data collation, compilation, and analysis. Data providers should prioritize refining processes to ensure robust data quality, consistency and interoperability. Doing this will allow researchers to tap into the full value of existing and future data.

**3. Explore Advanced Analytics and Diverse Analytic Approaches:** The exercises conducted during the hackathons shed light on the feasibility of using advanced analytics and diverse approaches for climate migration research.

**4. Address Critical Challenges:** The hackathons revealed critical challenges in harnessing environmental and climate-induced disaster data. Researchers must address issues such as spatial and temporal coverage limitations, data source incompatibility, and data interoperability constraints.

**5. Improve Data Accessibility:** The hackathon served as a catalyst for improving data accessibility. IOM should continue efforts to make mobility data more accessible to researchers, policymakers, and practitioners. Enhanced accessibility will empower stakeholders to continue improving the knowledge base on climate mobility.

### RECOMMENDATIONS FOR FUTURE RESEARCH:

**i. Machine Learning:** Investigate machine learning techniques to uncover patterns and trends within mobility data.

**ii. Understanding Journeys:** Explore journey-based analysis to better understand climate-related movements.

**iii. Intersectionality:** Incorporate analytic approaches that facilitate a more robust examination of the role different demographic characteristics play in climate mobility.

**iv. Integration of Migration and Climate Variables:** Define best practices and common approaches to merging large-scale datasets on human mobility with key climate data to enhance climate mobility analysis.

**v. Barriers and Facilitators:** Learn from participants' experiences during hackathons to better identify and define barriers, and facilitators in using different existing data sources for climate mobility research.

# APPENDICES AND REFERENCES

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# APPENDIX 1: LIST OF PARTICIPANTS

## A. NAIROBI EVENT

Participants listed here are contributors to this report through the analysis they produced during the hackathons.

| Team Composition | |
|---|---|
| **Name** | **Organisation** |
| **Team 1** | |
| Victor Villa | ABC |
| Daniel Ibanez | IOM |
| Aneeshaa Choudhury | UNDRR |
| Teo Ficcarelli | MMC |
| Markus Rudolf | Addis Ababa University |
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| Roberto Schiano | UNDRR |
| Olive Wangui Kirigo | MMC |
| Victor Kipkurui Korir | ABC |
| Khellia Munezero | IOM |
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| Joseph Mwangi | MMC |
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| Maxwell Oderoh | IOM |
| Rehema Batti | GNDR |
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| **AI Team** | |
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| Aminta Gutierrez | IOM |
| Kaho Yamaguchi | IOM |
| Nantege Patricia Grace Kawuma | IOM |
| Andualem Tadesse | IOM |

# B. LONDON EVENT

Participants listed here are contributors to this report through the analysis they produced during the hackathons.

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