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Climate and Migration in East and the Horn of Africa: Spatial Analysis of Migrants' Flows Data

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Acknowledgments

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About

The **Harvard Humanitarian Initiative (HHI)** is a university-wide academic and research center in humanitarian crisis and leadership. HHI is based at the Harvard T.H. Chan School of Public Health Department of Global Health and Population and is affiliated with the International Division of the Brigham Health Department of Emergency Medicine. As an Inter-Faculty Initiative (IFI), HHI collaborates closely with all Harvard Schools and Harvard Teaching Hospitals and is the primary humanitarian outreach arm of Harvard University. The mission of the Harvard Humanitarian Initiative is to create new knowledge and advance evidence-based leadership in disasters and humanitarian crisis. HHI was founded in 2005, currently operates 20 projects in 26 countries, and consists of 60 staff, faculty, affiliated faculty, students, fellows, and collaborators. HHI's aim is to promote interdisciplinary dialogue in pressing humanitarian issues, advance the science and practice of humanitarian response worldwide, and improve the lives of communities in war, conflict, and natural disasters. The Humanitarian Academy serves as the humanitarian hub of Harvard and is one of the first systematic educational programs for humanitarian practitioners focusing on capacity building in the form of humanitarian studies and experiential learning.

The **Humanitarian Geoanalytics Research and Education Program (HumGeo)** at HHI leverages the potential of geospatial data and analytics –including pattern analysis, geographically-weighted regression, optimization algorithms, and predictive modeling, to introduce new ways of thinking, identify targets for micro-planning and research, and optimize resource allocation for cost-effective programming.

The **International Organization for Migration (IOM)** is the leading intergovernmental organization in the field of migration and is committed to the principle that humane and orderly migration benefits migrants and society. IOM is part of the United Nations system, as a related organization. IOM supports migrants across the world, developing effective responses to the shifting dynamics of migration and, as such, is a key source of advice on migration policy and practice. The

organization works in emergency situations, developing the resilience of all people on the move, and particularly those in situations of vulnerability, as well as building capacity within governments to manage all forms and impacts of mobility.

The IOM Regional Data Hub (RDH) for the East and Horn of Africa (EHoA) aims to enhance technical coordination, harmonize different data collection activities and foster a multi-layered analysis of mixed migration movements, trends and characteristics across the region. Through a combination of IOM data collection methodologies, research initiatives, and continuous and active engagement with National Statistical Offices (NSOs), key line Ministries and Regional Economic Communities (RECs), the RDH aims to fill in the existing gaps in strengthening the regional evidence base on migration. This contribution will, in turn, help improve policy-making programming and coordination between all the stakeholders involved.

The Displacement Tracking Matrix (DTM) is a system to track and monitor displacement and population mobility, provide critical information to decision-makers and responders during crises, and contribute to better understandings of migration flows.

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Background

The drivers of human displacement are becoming more and more complex, ranging from conflict and persecution to the increasingly pertinent variables of heightened mobility and social media influences. Of rapidly but appropriately escalating concern is the impact of climate change. While the intensity and severity of climate-induced disasters and climate-related migration will be unevenly distributed across space and time, the World Bank estimates that approximately 140 million people will be displaced globally due to climate-related reasons by 2050.[1] The effects of climate change are expected to be particularly pronounced in Africa, where rising temperatures, unpredictable anomalous rainfall and high vulnerability to extreme natural hazards will continue to exacerbate conflict and harm local and regional human, economic, and environmental security.[2]

In the East and Horn of Africa (EHoA) in particular, the dependence on rain-fed agriculture and pastoralism means that livelihoods and food security are inextricably linked and affected by long-term or sudden environmental changes and natural hazards.[3] The extreme natural hazards that have struck EHoA in recent years have caused widespread hunger, displacement, loss of critical infrastructure and livelihoods, and death.[4] Climate projections further suggest that environmental changes will

> "the region appears set to be among those worst affected by the multiplier effects of climate change through above average temperatures, excessive or insufficient rainfall, desertification and environmental degradation."
>
> - UNISDR & IMDC, 2017

[1] *Midyear update: Climate displacement*. (2019, June 24). The New Humanitarian. https://www.thenewhumanitarian.org/feature/2019/06/24/climate-displacement-bangladesh-crisis-update

[2] Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham, and P. Urquhart. (2014) Africa. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge University Press,Cambridge, United Kingdom and New York, NY, USA, pp. 1199-1265.

[3] IGAD Climate Prediction & Application Centre and the World Food Programme Regional Bureau for East and Central Africa. (2017). *Greater Horn of Africa: Climate Risks and Food Security Atlas Technical Summary.* https://docs.wfp.org/api/documents/WFP-0000098939/download/

[4] Jerving, Sara. (2019, May 30). *Horn of Africa Burdened with crisis after crisis*. Devex. https://www.devex.com/news/horn-of-africa-burdened-with-crisis-after-crisis-92839

likely further lead to decreased water availability, lowered agricultural productivity, and increased disease transmission in the region,[5] producing complex ramifications regarding local and regional conflicts, economics, politics, and migration.

The porous borders in EHoA have contributed to some of the highest volumes of cross border movement in the world. In 2020 alone, EHoA hosted 6.5 million internally displaced persons (IDPs) and 3.5 million refugees and asylum seekers.[6] In the same year, the Horn of Africa experienced unusually high levels of precipitation leading to disastrous floods and landslides and creating ideal conditions for an detrimental locust plague towards the end of 2019 that devastated crops and disrupted livelihoods.[7] The extreme precipitation experienced across much of the Horn in 2019 was preceded by anomalous rainfall the previous year. 2018 was particularly hot and dry in the Horn of Africa, with positive temperature anomalies of around 2°C and below-average precipitation contributing to drought-like conditions in Somalia, Eritrea, and Djibouti while Kenya and Sudan experienced above-average precipitation.[8] The drought-like conditions in Somalia, Eritrea, and Djibouti contributed to widespread food insecurity that affected approximately 12 million people.[9] These extreme weather conditions are increasingly exacerbating the already complex and interconnected factors driving migration in the Horn of Africa, and are only expected to escalate in the future.

In an effort to understand the complex variables that influence migration, the International Organization for Migration (IOM) developed the Displacement Tracking Matrix (DTM) to track and gather information about populations on the move. The Flow Monitoring Registry (FMR) captures

[5] United Nations Development Programme (UNDP) Climate Change Adaptation. (N.d.). *Climate Vulnerability*. https://www.adaptation-undp.org/explore/africa

[6] International Organization for Migration (IOM). (2020). *A Region on the Move: 2020 Mobility Overview in the East an Horn of Africa and the Arab Peninsula*. https://ronairobi.iom.int/publications/region-move-2020.

[7] World Meteorological Organization. (2020). *State of the Climate in Africa*. (WMO-No. 1253). https://library.wmo.int/index.php?lvl=notice_display&id=21778#.X5a8zVNKhBw

[8] ACMED. (2019). *State of Climate of Africa in 2018*. http://www.acmad.net/new/sites/default/files/The-State-of-Climate-in-Africa-2018-Report-March-2018-March2019_Final.pdf

[9] FAO, 2019 as cited in: World Meteorological Organization. (2020). *State of the Climate in Africa.* (WMO-No. 1253). https://library.wmo.int/index.php?lvl=notice_display&id=21778#.X5a8zVNKhBw

a wealth of data about the migratory routes, the demographics and nationality of migrants, reasons for migration, modes of transportation used to facilitate movement, and vulnerabilities experienced by these populations. While the descriptive data provides a wealth of information, more can be done to analyze the complexities of and interactions between migration, conflict, environmental changes, and climate-related events.

For this study, the IOM RDH in Nairobi partnered with the Humanitarian Geoanalytics Program at the Harvard Humanitarian Initiative to leverage spatial analytics to investigate migration flows in the East and Horn of Africa and Yemen. Geospatial analytics hold tremendous potential to

introduce new ways of thinking, build research capacity, study impacts, and facilitate cost-effective programming. The adoption of geospatial methods into research oriented towards populations on the move, gives us the capacity to accurately characterize the spatial heterogeneity of migrating populations. Furthermore, by incorporating environmental variables into this spatial analysis, we begin to reveal relationships previously undiscovered that could contribute to a richer understanding regarding migration in the region.

Scope of research

This research used FMR data to examine out-migration and the drivers thereof in the East and Horn of Africa and Yemen (EHoA+Y) to build a better understanding of spatiotemporal trends of migration and displacement and to highlight how natural disasters and environmental variables have affected displacement and migration in the region. Specifically, this research examined the spatial and temporal patterns of out-migration in EHoA+Y between 2018 and 2020, changing reasons for out-migration, and the correlation between rainfall, temperature and out-migration. This research aims to answer the following questions through a variety of geospatial analyses:

1) How did out-migration rates in any given administrative region change over time and, was it statistically significant compared to administrative regions around it?

2) How do the *numbers of migrants* and the *overall migration trends* vary across space and time, for each cited reason for migration (aka 'driver of migration')?

3) How do environmental variables, e.g. temperature and precipitation, correlate with out-migration in in the East and Horn of Africa?

This research provides new insights into out-migration patterns in the region, demonstrates a novel way to investigate changing reasons for out-migration, and establishes a foundation for future studies to analyze the complex and evolving relationship between migration and climate change that will continue to intensify in the years to come.

Methodology

Data

Flow Monitoring Registry

This analysis used IOMs Flow Monitoring Registry data collected between January 2018 and September 2020 in the East and Horn of Africa and Yemen. The FMR data contains information about migrant's nationality, age, sex, vulnerability, departure location, reason for migration, and intended destination, among other variables. The data is captured by trained enumerators at Flow Monitoring Points (FMPs) which were predetermined to be locations of high cross-border migration.[10]

Figure 1. Study area

This analysis considered respondents whose departing location was in Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan, or Yemen (hereafter collectively referred to as EHoAEHoA+Y) (Figure 1). Approximately 99.4% of respondents departed from one of these seven countries while the remaining 0.6% departed from other countries. The analysis was conducted at the first administrative level (or admin 1) excluding entries that either did not contain information about the admin 1 departure location or if the departure location was incorrectly entered. As a result of the aforementioned data cleaning, 97.19% of those surveyed were included in this analysis (Table 1). The location of departure was used for this analysis because 1) the reported destination was

[10] IOM DTM Flow Monitoring. (2018). *Migration Flows in the Horn of Africa and Yemen*. https://migration.iom.int/data-stories/migration-flows-horn-africa-and-yemen

not guaranteed, as migrants were surveyed in transit prior to completion of their journey, 2) information regarding destination location often incomplete or vague, and 3) when considering 'push' variables for migration, such as climate change, location of departure or 'origin' is likely the most relevant.

Table 1. Total survey responses per country included in this analysis

Country of Departure	Survey count	% of total respondents
Djibouti	14,288	7.03%
Eritrea	2,490	1.22%
Ethiopia	107,309	52.78%
Kenya	10,723	5.27%
Somalia	43,765	21.52%
Sudan	22,991	11.31%
Yemen	1,767	0.87%

For parts of the spatial analysis (see "Spatial Analysis" below), the FMR data was aggregated into seasons between January – December (Table 2) in order to be able to compare across seasons and account for possible seasonal migration trends. Given the disparate seasonality across the region, the seasons were abstractly designed for methodological consistency. Then, the total number of migrants per administrative unit were divided by the total number of days per season, producing an average migration rate per day for that season.

Table 2. Seasonal aggregation used for this research

	2018	2019	2020
Seasons included	Jan-Mar	Jan-Mar	Jan-Mar
	Apr-Jun	Apr-Jun	Apr-Jun
	July-Sept	July-Sept	July-Sept
	Oct-Dec	Oct-Dec	

Environmental Variables and Climate-Related Disasters

Temperature and Precipitation | To determine how environmental variability correlated with out-migration in the region, this research incorporated open-source data on precipitation from the Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS)[11] and land surface temperature (LST) from the Global Historical Climatology Network Climate Anomaly Monitoring System (GHCN CAMS)[12]. Both data are gridded (raster) datasets: the precipitation data captures millimeters of rain per month (mm/month) at a spatial resolution of 5 km while the LST captures mean land surface temperature (LST/month) at a spatial resolution of 50 km. The information was extracted and aggregated by the administrative 1 level for further analysis. Temperature and precipitation are some of the most utilized variables to examine the relationship between environmental change and migration and were considered appropriate for this analysis.[13,14]

Climate-related Disasters | Climate-related disaster data from EM-DAT and the Internal Displacement Monitoring Center (IDMC) were used to retrospectively cross-tabulate noted migration trends with recorded natural hazards in the region between 2018 and 2020. There was substantial overlap between the two datasets, but they each carried unique information that was deemed valuable and complementary for this analysis. For a natural disaster to be recorded by EM-DAT, the event must have either killed 10 or more people, affected upwards of 100 people, resulted in a state of emergency, or forced the government to request international assistance.[15] EM-DAT recorded 55 events in EHoA that were included in this analysis. The IDMC dataset on the other hand, was generated by combining country-specific annual disaster data that manifested between 2018 and 2019. The IDMC consults local, national, government, and international bodies

[11] Funk, C.C., Peterson, P.J., Landsfeld, M.F., Pedreros, D.H., Verdin, J.P., Rowland, J.D., Romero, B.E., Husak, G.J., Michaelsen, J.C., and Verdin, A.P. (2014). A quasi-global precipitation time series for drought monitoring: U.S. Geological Survey Data Series 832, 4 p. ftp://chg-ftpout.geog.ucsb.edu/pub/org/chg/products/CHIRPS-2.0/docs/USGS-DS832.CHIRPS.pdf

[12] Fan, Y., and H. van den Dool (2008), *A global monthly land surface air temperature analysis for 1948-present*, J. Geophys. Res., 113, D01103, doi:10.1029/2007JD008470.

[13] Mastrorillo, M., Licker, R., Bohra-Mishra, P., Fagiolo, G., Estes, L. D., & Oppenheimer, M. (2016). *The influence of climate variability on internal migration flows in South Africa*. Global Environmental Change, 39, 155-169.

[14] Mueller, V., Sheriff, G., Dou, X., & Gray, C. (2020). *Temporary migration and climate variation in eastern Africa.* World development, 126, 104704.

[15] EM-DAT. (N.d). *Database Classification*. https://www.emdat.be/explanatory-notes

in addition to existing data, news, and media outlets.[16] The IDMC dataset included 49 weather-related events in Ethiopia, Yemen, Kenya, Somalia, and Djibouti.

[16] Internal Displacement Monitoring Center. (N.d.). *Methodology*. https://www.internal-displacement.org/database/methodology

Spatial Analysis

Four complementary spatial analytic methods were used for this research – choropleth maps, cluster analysis, time series clustering, and geographically-weighted regression. Each method is introduced and described in below.

Choropleth Mapping

Choropleth maps were used to visualize the average daily number of migrants departing their indicated administrative unit of origin, aggregated by season. Choropleth maps enabled comparisons of average daily migration rates across seasons *within* the same year or *between* years. Change rates across years reveal how migration rates compare between seasons in 2018, 2019, and part of 2020 answering the question: How did migration rates in any given administrative region change over space and time Simply understanding how migration rates vary across time and space can inform programming and allow for better targeting of resources. Choropleth maps are one of the easiest spatial data representations to understand, and convey a lot of information quickly, but are bereft of statistical analysis.

Choropleth mapping explained: Choropleth maps are thematic figures that capture differences in data values through colors or patterns. See ArcGIS Insights for more information about choropleth mapping.

Cluster Analysis

Cluster analysis was used to identify large scale spatial patterns of change in migration rates across the study area between each season which was then compared across years. Change rates across years revealed how migration rates compare between season in 2018, 2019, and part of 2020 answering the question: did migration rates in any given administrative region change and if so, was it statistically significant compared to administrative regions around it? Identifying administrative regions that have experienced statistically significant out-migration between 2018 and 2020 could warrant further a localized investigation of the drivers of out-migration in these regions to more granularly understand out-migration and the reasons thereof.

Cluster and outlier analysis explained: Cluster and outlier analysis identifies groups of neighboring communities that possess similar values (i.e. clusters) and communities that significantly differ from those around them (i.e. outliers). If a feature (in this case, a single administrative area) has out-migration values that are similar to its surrounding features, then the feature is a part of a cluster. If a feature has dissimilar values to surrounding features, then the feature is considered an outlier. See the ArcGIS Pro Help Page for more information about cluster and outlier analysis.

Time Series Clustering

Time series clustering was utilized to identify and group administrative units that shared similar n*umbers/values* or *trends (i.e. increasing or decreasing rates)* of economic or disaster-driven out-migration between 2018 and 2020. Grouping administrative units with similar *values* of out-migration answers the question: which administrations have high numbers of out-migration and how does this fluctuate over time? While grouping administrative units with similar *trends* highlight which administrations experienced a relative increasing or decreasing trend in out-migration, regardless of the number of migrants.

Time series clustering explained: Time series clustering identifies trends and patterns across space and time, grouping features that share similar characteristics in three different ways. Data can be analyzed using 1) *values* to determine clusters of features with similar numbers over time, 2) *correlations* to capture similarities in proportional trends across time, or 3) the *profile* of the data to capture fluctuations in the time series. See this ArcGIS Pro Help page or this ArcGIS Blog for more information about time series clustering.

Regressions

To characterize the relationship between climate variables and migration rates, Ordinary Least Squared (OLS) and Geographically-Weighted Regression (GWR) methods were employed, defining

temperature and precipitation as the independent variables and migration rates as the dependent variable. OLS was used first, to determine these relationships bereft of the spatial variable, and then the GWR was used to characterize the association between temperature, precipitation, and migration rates and how those relationships varied across the region. In other words, the GWR reveals the strength of the relationship. The GWR was iterated in three different ways to test the relationship between 1) temperature and migration, 2) precipitation and migration, 3) temperature, precipitation, and migration. These iterations capture which model most accurately described the relationship between these environmental variables and migration rates.

Ordinary Least Squared (OLS) explained: OLS is a global linear regression technique used to capture the relationship of one or more independent variables and the dependent variable. It is best practice to use OLS prior to running a GWR. See this ArcGIS Pro Help page for more information about OLS.

Geographically-Weighted Regressions (GWR) explained: GWR is a local linear regression that considers how space influences the relationship between the model's independent and dependent variables. See this ArcGIS Pro Help page for more information about geographically weighted regressions.

Limitations

The limitations of this project are primarily related to the availability of (granular) geo-coded data and sparse contextual information. First, while the FMR data includes information about the country and administrative regions (level 1 and 2) of, the location information at the admin 2 level was relatively limited, requiring the use of admin 1, which resulted in a less granular analysis. Similarly, the temperature data used for this analysis was quite course, obscuring local temperature variability. Furthermore, conflict and economic variables were not considered in this analysis, though these are variables assumed to play an important role in out-migration. Future

analysis would also benefit from on-the-ground data collection to help contextualize statistical outcomes.

Results

Space plays an inherently important role in migration and displacement. **This study's utilization of spatial statistics highlights the variability of migration patterns and trends over time, draws out otherwise unseen spatial relationships between migration and climate variables, and provides empirical evidence to support already documented out-migration trends across Djibouti, Eritrea, Ethiopia, Sudan, Somalia, Yemen, and Kenya between 2018 and 2020.**

Characterizing annual migration

The choropleth maps below (Figure 2) provide a large-scale, spatio-temporal overview of changing migration rates across the EHoA+Y region between 2018 and 2020. While there is an expected drop off in migration as the region began restricting cross-border movement with the advent of the COVID-19 pandemic,[17] there are also several other interesting more localized trends.

- **Ethiopia**: Between January 2018 and August 2020, Ethiopia consistently generated the highest rates of out-migration across the EHoA+Y region, with most migration originating in the Somali, Oromia, and Tigray regions, as seen in Figure 3. The highest average daily migration in all three regions was between April and June 2018, when there was an average of over 290 daily departures. Potentially attributable to the region's comparative vulnerability to climate-related disasters such as floods, cyclones, and droughts during this

[17] IOM Regional Office for East and Horn of Africa. (2020). *Impact of COVID-19 Movement Restrictions on Migrants along the Eastern Corridor*. IOM. https://migration.iom.int/reports/impact-covid-19-movement-restrictions-migrants-along-eastern-corridor?close=true

period,[18,19] this trend also likely reflects escalating ethnic clashes in the regions of Gedeo and West Guji and along the Somali border.[20]

- Somalia: During this same period, several administrative regions in northern and southern Somalia experienced an uptick in migration, with approximately 21 to 70 people departing per day.
- Kenya: In eastern Kenya, a similar increase occurred but several months later between January and March 2019. However, in general, the majority of administrative areas in the region in 2018 and 2019 experienced comparatively low migration flows with fewer than 21 people/day departing, seasonally.

[18] EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.
[19] Internal Displacement Monitoring Center. Weather-related events data. www.internal-displacement.org. Note: data was aggregated from individual country profiles.
[20] Christin Roby. (2018, September 13). *Ethiopia displacement crisis skyrockets*. Devex. https://www.devex.com/news/ethiopia-displacement-crisis-skyrockets-93422

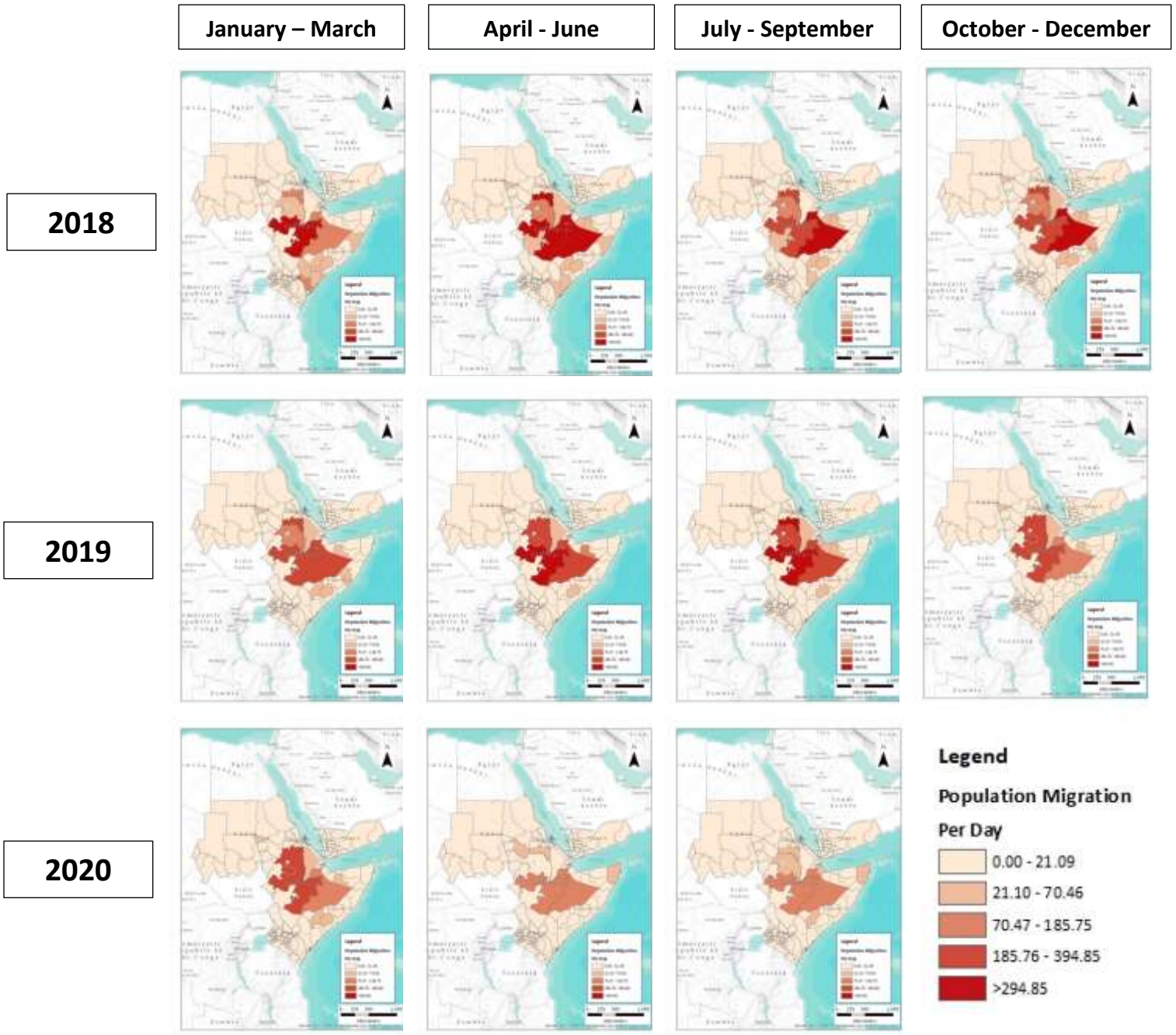


Figure 2. Choropleth maps of average daily rates of out-migration from each administrative one district in the EHoA+Y study by season across 2018 to 2020.

Migration Clusters and Outliers

The cluster and outlier analysis of the FMR data (Figure 3) yielded multiple compelling results across the study period, with several regional clusters of increasing out-migration between years and a considerable number of districts displaying anomalously increasing out-migration in comparison to neighboring regions.

- Clusters of increasing out-migration: between 2018 and 2019, during January – March, clusters of increasing out-migration are seen in Eritrea, northern Ethiopia, and Woqooyi Galbeed in the northern region of Somalia. This finding is temporally associated with a drought that occurred in this region during January 2019.[21]

- Clusters of decreasing out-migration: during the same period, there are clusters of decreasing out-migration in southeastern Kenya and Southern Somalia. However, the administrative districts in southern Kenya did demonstrate an alarming trend of escalating out-migration in comparison to the rest of the EHoA+Y study region, as is evidenced by April – June 2018 vs. 2019, October – December 2018 vs. 2019, and July – September 2019 vs. 2020 comparisons. This trend cannot be directly associated with specific climate-related disasters, and may represent conflict, economic, or policy changes in the region.

- Notably, clusters of increasing out-migration rates in Oromia and Amhara in Ethiopia, and Gedaref in Sudan at the beginning of 2020 are critical to recognize, and are temporally associated with a cholera outbreak[22] in that region, but alternate variables are more likely to have caused this trend. And, clearly, the trend is disrupted, likely due to the surge of COVID-19. Given the outbreak of violence in the northern region of Ethiopia and Eritrea at the end of 2020,[23] a compelling result was the comparably high levels of out-migration seen in the Gash Barka and Dedub regions in Eritrea, starting in April 2020. These outliers may reflect growing tensions in the region and could potentially represent early indicators

[21] Internal Displacement Monitoring Center. Weather-related events data. www.internal-displacement.org. Note: data was aggregated from individual country profiles.
[22] EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.
[23] Dahir, Ilhan. (2020, December 21). *Rising Number Flee Ethiopia as Internal Conflict Persists.* IPI Global Observatory. https://theglobalobservatory.org/2020/12/rising-numbers-flee-ethiopia-as-internal-conflict-persists/

of ensuing large-scale violence. These districts are joined by Benishangul Gumuz and the SNNP regions of Ethiopia later in the year, and while there is a documented flood that affected the region at the end of April 2020,[24] conflict is far more the likely driver of this trend.

[24] EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.

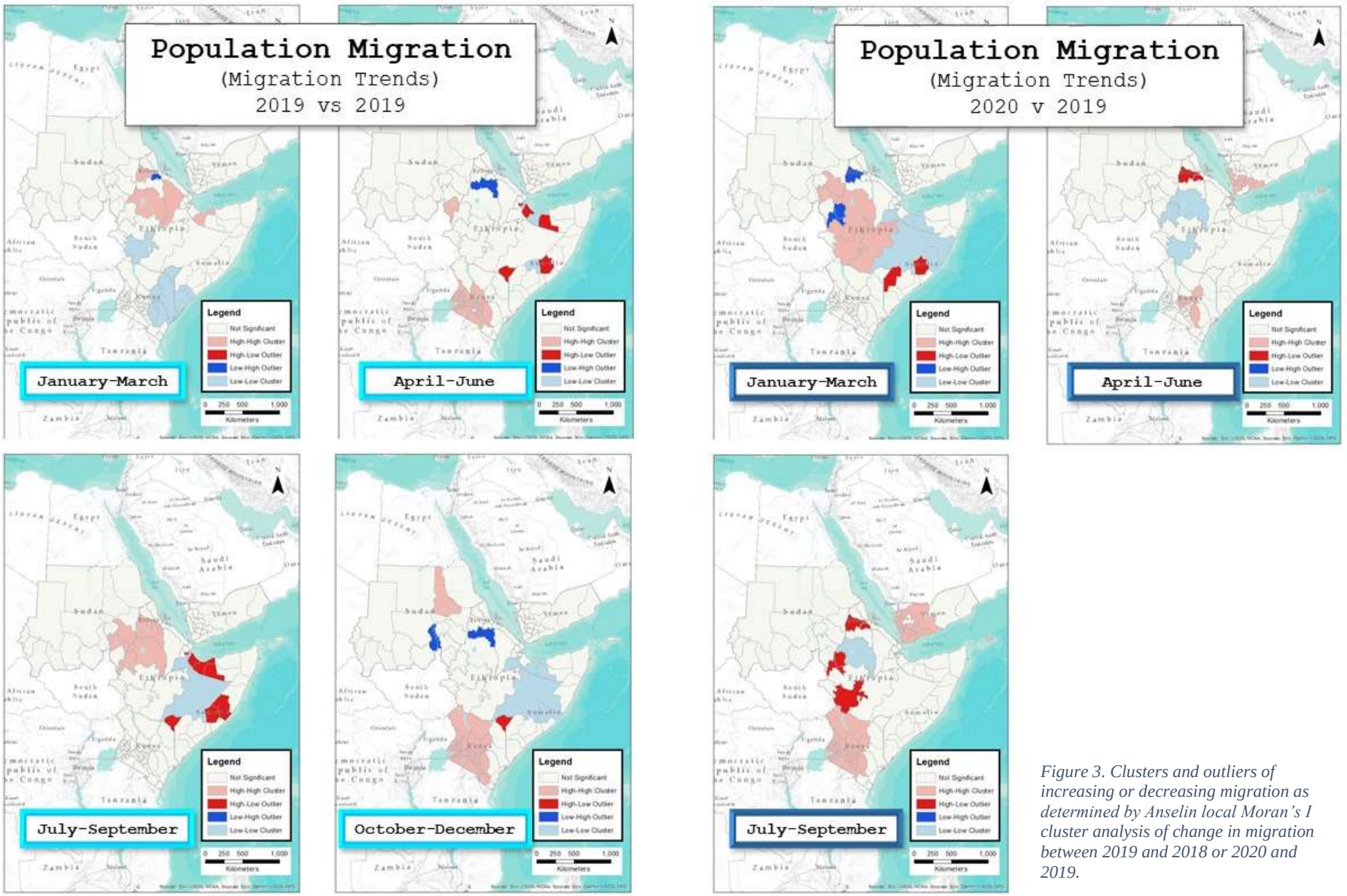


Figure 3. Clusters and outliers of increasing or decreasing migration as determined by Anselin local Moran's I cluster analysis of change in migration between 2019 and 2018 or 2020 and 2019.

Notably, clusters of increasing out-migration rates in Oromia and Amhara in Ethiopia, and Gedaref in Sudan at the beginning of 2020 are critical to recognize, and are temporally associated with a cholera outbreak[25] in that region, but alternate variables are more likely to have caused this trend. And, clearly, the trend is disrupted, likely due to the surge of COVID-19. Given the outbreak of violence in the northern region of Ethiopia and Eritrea at the end of 2020,[26] a compelling result was the comparably high levels of out-migration seen in the Gash Barka and Dedub regions in Eritrea, starting in April 2020. These outliers may reflect growing tensions in the region and could potentially represent early indicators of ensuing large-scale violence. These districts are joined by Benishangul Gumuz and the SNNP regions of Ethiopia later in the year, and while there is a documented flood that affected the region at the end of April 2020,[27] conflict is far more the likely driver of this trend.

Drivers of Migration

Time series cluster analysis of the reasons for migration captured in the FMR dataset produced several disparate narratives regarding why migrants from specific districts in the EHoA+Y region migrated over time. The FMR dataset captures respondents' given reason for migration, including 1) economic reasons 2) conflict, 3) natural disasters, 4) seasonal, 5) tourism, 6) other. Here, disaster- and economic-related migration are discussed, given the theoretical and previously documented associations between climate, natural disasters, and livelihoods. The graphics in this section group administrative regions if they have comparable *numbers* (numbers of migrants) and behavioral *trends* (increasing vs. decreasing) of out-migration associated with these given reasons for migration.

Disaster-related migration

[25] EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.
[26] Dahir, Ilhan. (2020, December 21). *Rising Number Flee Ethiopia as Internal Conflict Persists.* IPI Global Observatory. https://theglobalobservatory.org/2020/12/rising-numbers-flee-ethiopia-as-internal-conflict-persists/
[27] EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.

Numbers of out-migration analysis| Overall, a very low number of respondents cited natural disasters as their reason for migration. However, as seen in Figure 4, almost 2,000 FMR survey respondents indicated that their reason for departure out of Somali, Ethiopia was related to natural disasters in August 2018, evidencing an anomalous increase in disaster-related migration in both the EHoA+Y region and over the study period. However, this administrative region experienced significantly more disaster-related migration compared to any other administration in the region in general. While this region was cited as experiencing multiple climate-related disasters[28] between 2018 and 2020, surrounding districts were also impacted, and did not manifest in such high levels of out-migration. In comparison, the Dire Dawa district of Ethiopia did experience a similar spike in natural disaster-driven migration in July 2018, although the number of migrants was not nearly as extreme.

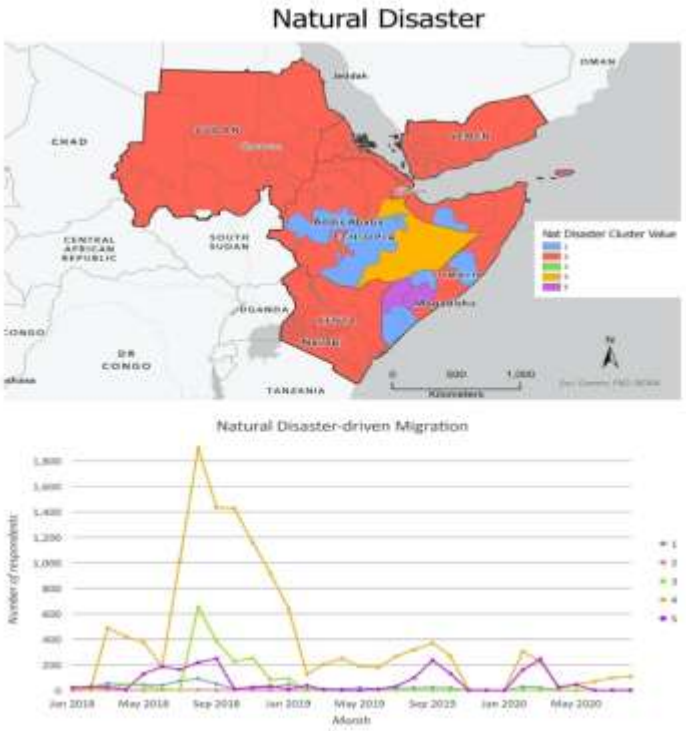


Figure 2. Numbers of out-migration analysis: administrations grouped if they have similar number of disaster-driven migration over time

[28] EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.

Trend analysis | While the *numbers* of disaster-driven migrants originated mainly from within Ethiopia, the migration time series *trend* analysis indicates that there was a regionally broader increase in disaster-driven migration across much of the EhoA+Y region, specifically noting Eritrea, Southern Ethiopia, central Sudan, Yemen, and parts of Somalia beginning in late 2018 (Figure 5). These results are likely to be a more accurate representation of the impact of the significant number of climate-related disasters affecting the region[29] as opposed to reflecting the size of each district's population and/or sampling bias. Notwithstanding this extreme but relatively brief uptick in disaster-induced migration in Kenya, Northern Ethiopia, and parts of Yemen and Somalia, there was a steep decline that remained low (and yet still varied) for the duration of the study period.

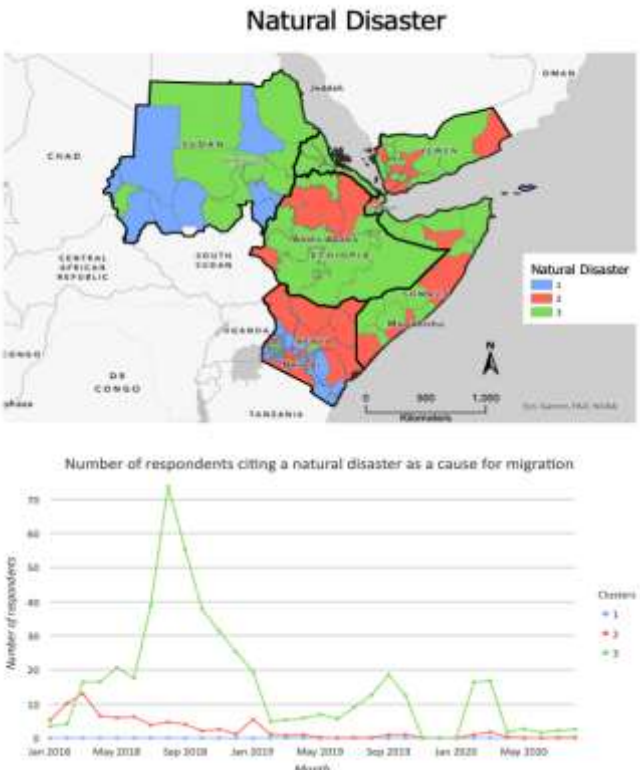


Figure 3. Trend analysis: administrations grouped if they have shared trends in disaster-driven out-migration over time

Clusters 2 and 3 showed significantly lower disaster-related migration trends, but Cluster 2 (including much of Kenya, northern Ethiopia, Eritrea, and parts of Somalia) did demonstrate some variability, with higher levels of disaster-related migration during the earlier part of the study period and lower out-migration after January 2019. Cluster 3 evidenced no significant disaster-related out-migration, which may be an artifact of data collection or a reflection of alternate drivers of migration in those regions.

[29] EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.

Economic Migration

Numbers of out-migration analysis | Economic migration was the most commonly cited reason for outmigration in general. As seen in Figure 6, many of the administrations in East Africa have relatively low numbers of economic migrants and most of the variability and the highest number of economic migrants originate from within Ethiopia. Between January 2018 and July 2018, the number of economic migrants from Amhara, Ethiopia increased from 100 migrants to over 1,120. Economic migrants from SNNP and Somali, Ethiopia also experience a similar increase in the numbers of economic migrants around the same time, but the number of migrants departing these regions drops from an average of over 700 respondents to under 200 between September and October 2018. Economic migration throughout the region rapidly decreased in mid-2020, which corresponds with COVID-19 border restrictions.

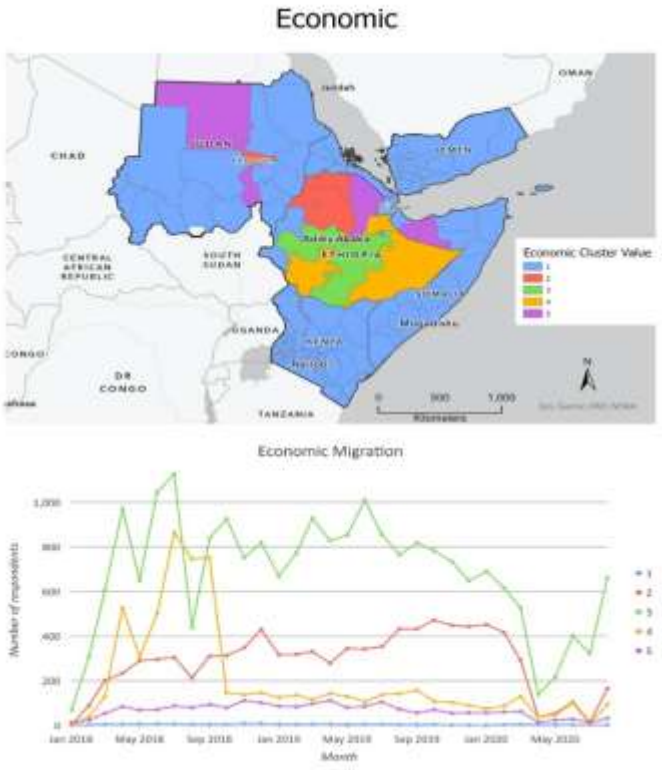
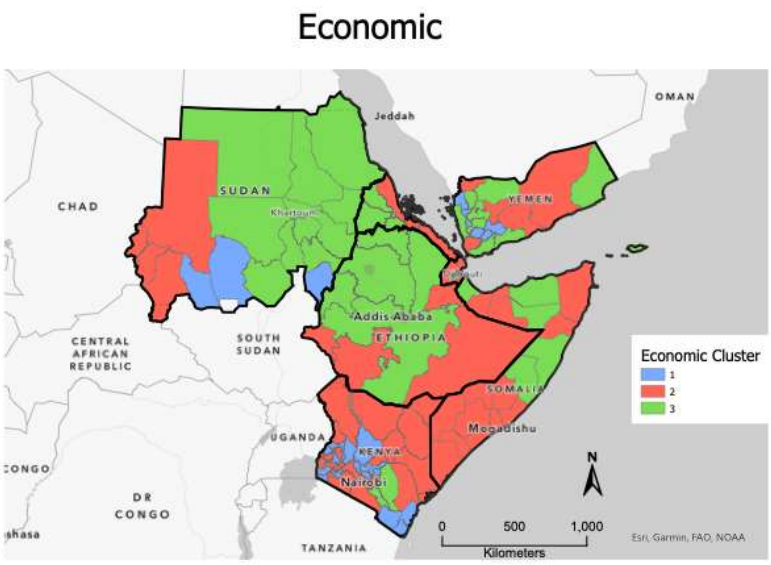


Figure 4. Numbers of out-migration analysis: administrations grouped if they have similar numbers of economic out-migration

Trend analysis | Most of administrations in the study region experienced similar *trends* in economic migration between 2018 and 2020 and can be grouped into three clusters (Figure 7). Cluster 1 includes very peripheral administrations (Southern Sudan, Southern Kenya, and parts of Western Yemen) with virtually no economic out-migration. Cluster 2 includes most of Kenya, Southern Somalia, Central Yemen, Western Sudan, and Southern Ethiopia. This cluster experiences an increase in economic out-migration from January 2018 until August 2018, after which it experiences a sudden and steep decline that remains stable/low for the remainder of the study

period. Cluster 3 includes most of Ethiopia, Sudan, northern Somalia, and Eritrea, and experiences similar trends to that of Cluster 2 but instead of decreasing in late 2018, continues to have high economically-related out-migration until May 2020. With an understandably significant drop in economically-driven out-migration in early 2020, there still remains critical variations in this migration flow in Cluster 3.



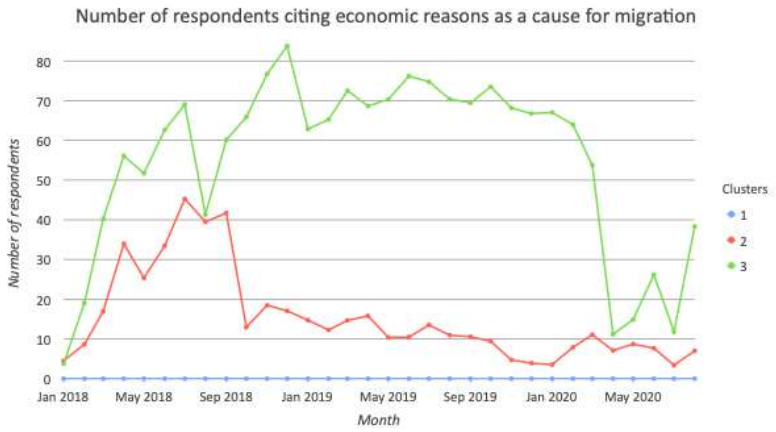


Figure 5. Trend analysis: administrations grouped if they have shared trends in economic out-migration over time.

Temperature, Precipitation, and Migration

Results of the regression analyses correlating all-cause migration rates with temperature and precipitation (Figures 8 and 9) evidenced a definitive association between environmental variables and migration, but these relationships are not consistent in either strength or direction across space and/or time in the EHoA+Y study area. While a non-linear relationship between these environmental variables and migration complicates the climate/migration narrative, there were interesting trends derived from this work. Two such trends illuminated by iterative GWR analyses are 1) temperature is most strongly associated with out-migration between January and March across the region, and 2) precipitation is more relevant than temperature in explaining out-migration between July and September. This suggests that the influence of temperature and precipitation on out-migration is variable and non-linear. These findings are further explored, below.

Temperature

Between January and March 2018, districts in southeast Kenya and southern Somalia showed a strong association between increases in temperature and increases in out-migration. This relationship likely reflects the dry season that Kenya experienced between December and March,[30] with overall higher temperatures and lower average precipitation likely leading to higher degrees of climate-related stress on livelihoods. The strength of the relationship in these areas decreases somewhat during the same time period in 2019 and 2020. In these later years, a similarly direct relationship between temperature and migration emerges in Bari, Somalia, and Haudramaut and Al Mahara, Yemen where decreasing annual rainfall[31] and water availability may

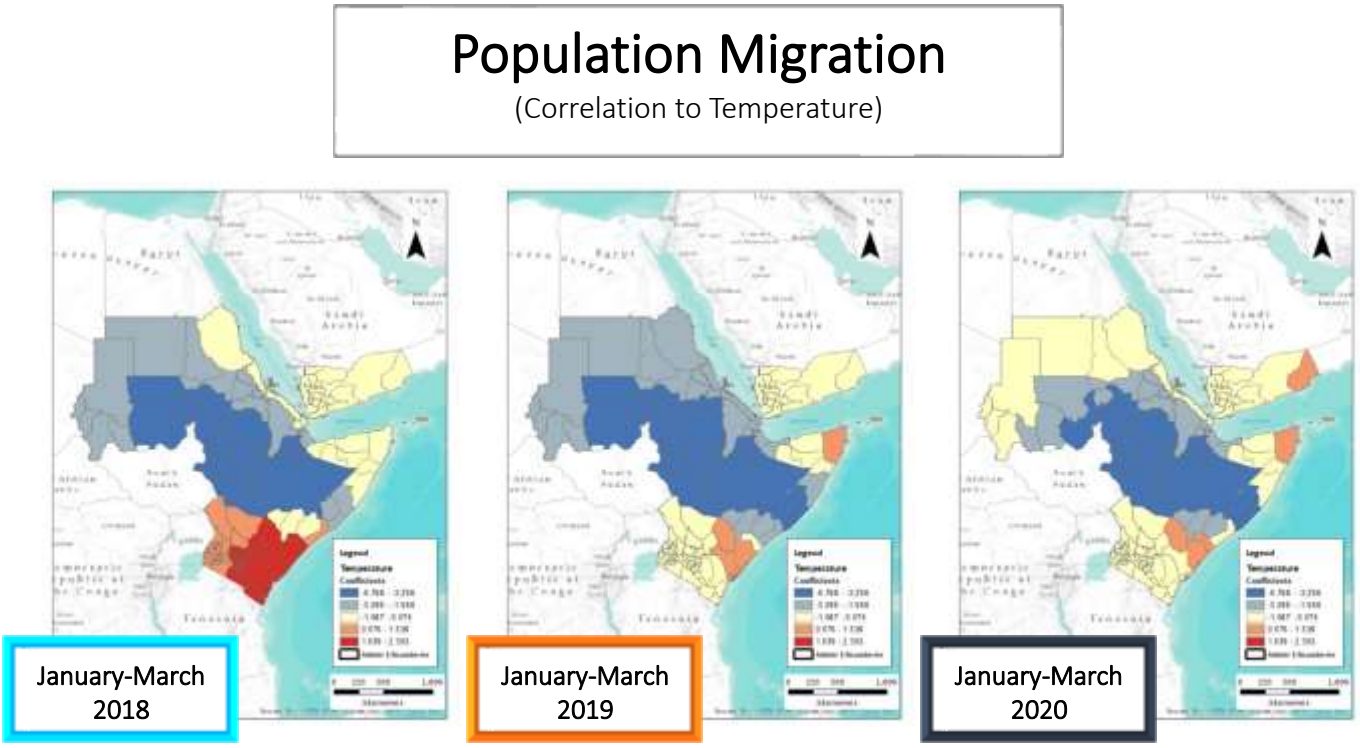


Figure 6. Association between temperature and migration. Hues of red: increase in temperature = increase in migration, Hues of blue: increase in temperature = decrease in migration

[30] World Weather Online. (N.d.) *Malindi Monthly Climate Averages, Coast, KE*. https://www.worldweatheronline.com/malindi-weather-averages/coast/ke.aspx
[31] World Weather Online. (N.d.). *Ad Dirah Monthly Climate Averages, Hadramawt, YE.* https://www.worldweatheronline.com/ad-dirah-weather-averages/hadramawt/ye.aspx

be exacerbating heat-related stress. In fact, a drought that continued to plagued parts of Somalia in January 2019[32] is likely to contribute to these findings.

Conversely, increases in temperature in parts of Ethiopia and Sudan are seen to be associated with a decrease in out-migration between January and March across all three years during this season. While similar rainy/dry seasons apply to these regions, annual precipitation rates[33] in these districts are significantly higher and may change the relationship between average ground temperature and out-migration. However, it should be emphasized that environmental factors are only a component of a complex amalgam of variables that influence migration, and drivers such as political and ethnic tensions, outright conflict, or economic considerations may be confounding these findings.

[32] UN OCHA. (2019, February 5) *Humanitarian Bulletin Somalia*. UN OCHA, posted on ReliefWeb. https://reliefweb.int/report/somalia/humanitarian-bulletin-somalia-1-january-5-february-2019-enso.
[33] World Weather Online. (N..)d. *Asosa Monthly Climate Averages, ET*. https://www.worldweatheronline.com/asosa-weather-averages/et.aspx

Precipitation

Precipitation was also shown to have a complicated relationship with out-migration in the EHoA+Y region. While understandable, given that very low levels of rain may produce droughts and extremely high levels of precipitation may indicate potential floods or cyclones, this non-linear relationship between average precipitation and suitable living conditions obscures any direct relationship between the variable and out-migration. However, several findings are pertinent to better understanding these associations. For example, during the July-September season, low levels of precipitation are associated with increased out-migration in much of Kenya, central Ethiopia, Sudan, and Yemen in all years. This result likely reflects the mitigating effect that rain and water availability has on migration. Droughts during this time period, as was seen in Kenya between December 2018 and August 2019,[34] likely reinforce and explain this relationship.

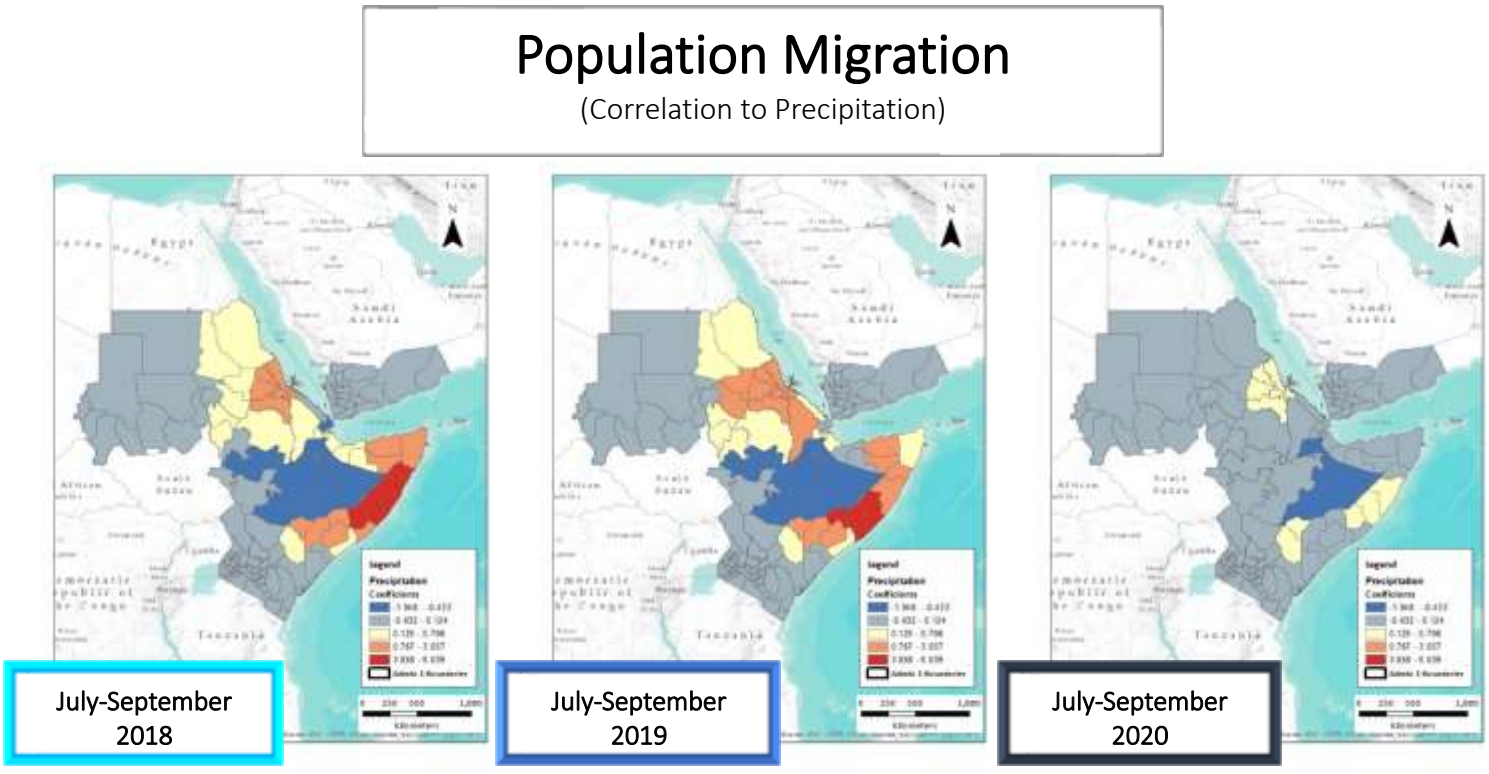


Figure 7. Association between precipitation and migration. Hues of red: increase in precipitation = increase in migration, Hues of blue: increase in precipitation = decrease in migration.

[34] FEWS NET. (N.d). *Crisis (IPC Phase 3) to persist in the short-term due to prior drought and current heavy rainfall.* FEWS NET. https://fews.net/east-africa/kenya/food-security-outlook/october-2019

However, the inverse relationship can be seen in Somalia, parts of Eritrea, and northern Ethiopia during 2018 and 2019, where high precipitation is associated with increased out-migration. Interrogation of the 'the reason for migration' reported in the FMR dataset reveals that these regions were experiencing higher disaster-related outmigration during these times. And, in fact, floods documented by IDMC were likely the cause of this trend.[35] Barring a climate-related disaster event, as seen in 2020, the trends in these regions converged with that of the larger EHoA+Y study area wherein increases in precipitation was associated with decreases in migration.

[35] Internal Displacement Monitoring Center. Weather-related events data. www.internal-displacement.org. Note: data was aggregated from individual country profiles.

Environment and Migration in the East and Horn of Africa

As previously emphasized, migration patterns in East and the Horn of Africa are driven by a myriad of reasons, with climate playing an increasingly influential role. This study reveals not only interesting spatio-temporal trends in all-cause migration that could, after further research, potentially inform policy and programming, but also highlights the plausible relationship between out-migration, climate variables, and previously documented, climate-related disasters (Figures 10 and 11).

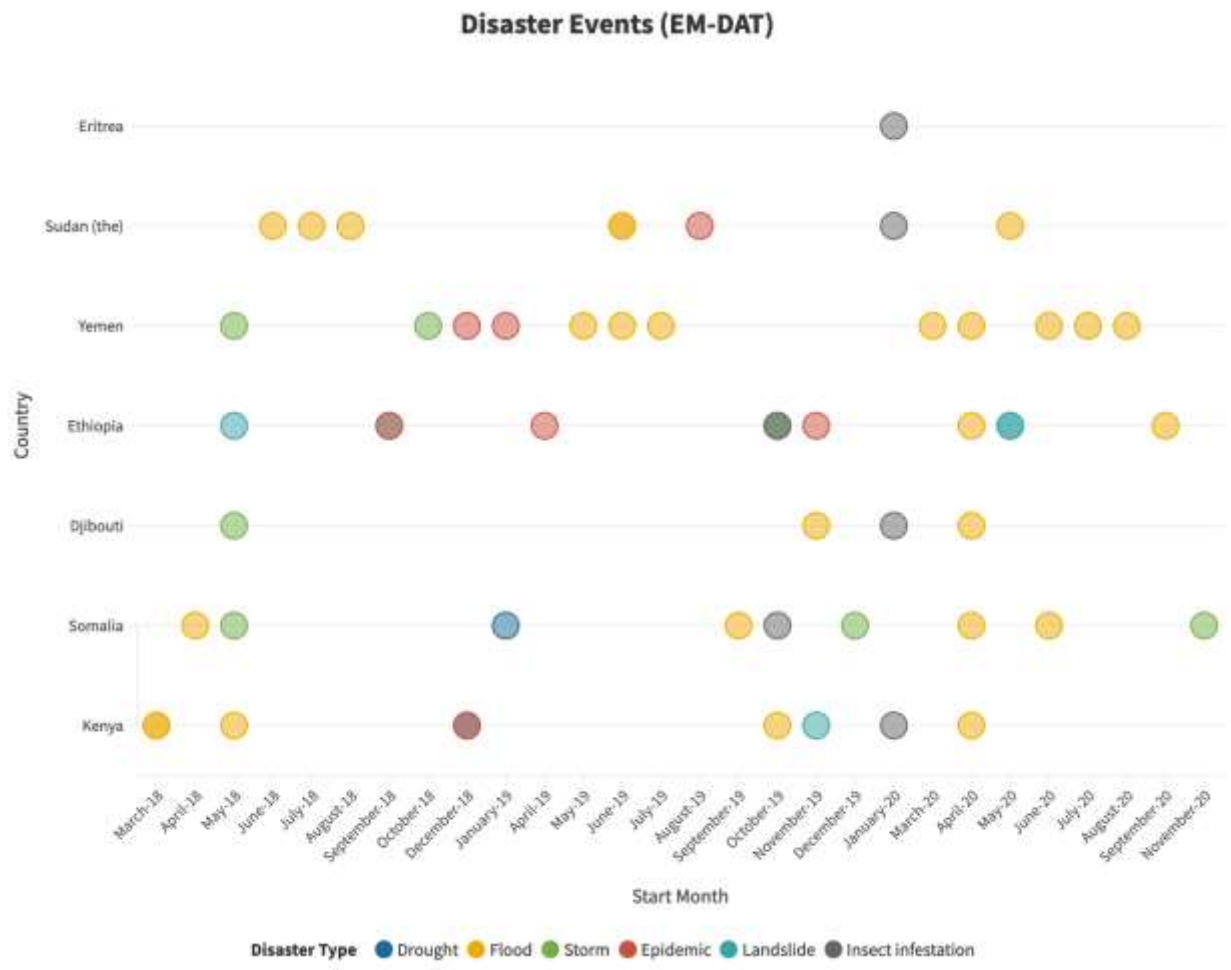


Figure 18. Data source: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.. Figure created using Flourish.

For example, the increase in disaster-related migration in mid-2018 revealed in the time series clustering analysis coincides with historic storms, such as cyclone Sagar, and several floods that

affected parts of Kenya, Ethiopia, and Somalia in April and May 2018.[36,37,38] UNOCHA reported flash floods specifically in Somali, Ethiopia that inundated over 50,000 households and displaced more than 30,000 people[39] – a trend that is reflected in the consistently high out-migration seen in our analysis from that admin region. Flooding was tragically followed by cholera outbreaks in

[36] EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.
[37] Jerving, Sara. (2019, May 30). *Horn of Africa Burdened with crisis after crisis*. Devex. https://www.devex.com/news/horn-of-africa-burdened-with-crisis-after-crisis-92839
[38] Internal Displacement Monitoring Center. Weather-related events data. www.internal-displacement.org. Note: data was aggregated from individual country profiles.
[39] UN OCHA. (2018, May 22). *Ethiopia- Floods Flash Update #3*. ReliefWeb. https://reliefweb.int/report/ethiopia/ethiopia-floods-flash-update-3-22-may-2018

Ethiopia, Yemen, and Kenya., which likely contributed to the regional spike in disaster-related out-migration.[40]

While disaster-induced migration experienced a dramatic increase in early to mid-2018, it is an infrequently cited driver of out-migration when compared to alternate causes cited in the FMR. Economic migration, on the other hand, is a highly-cited driver of migration throughout the

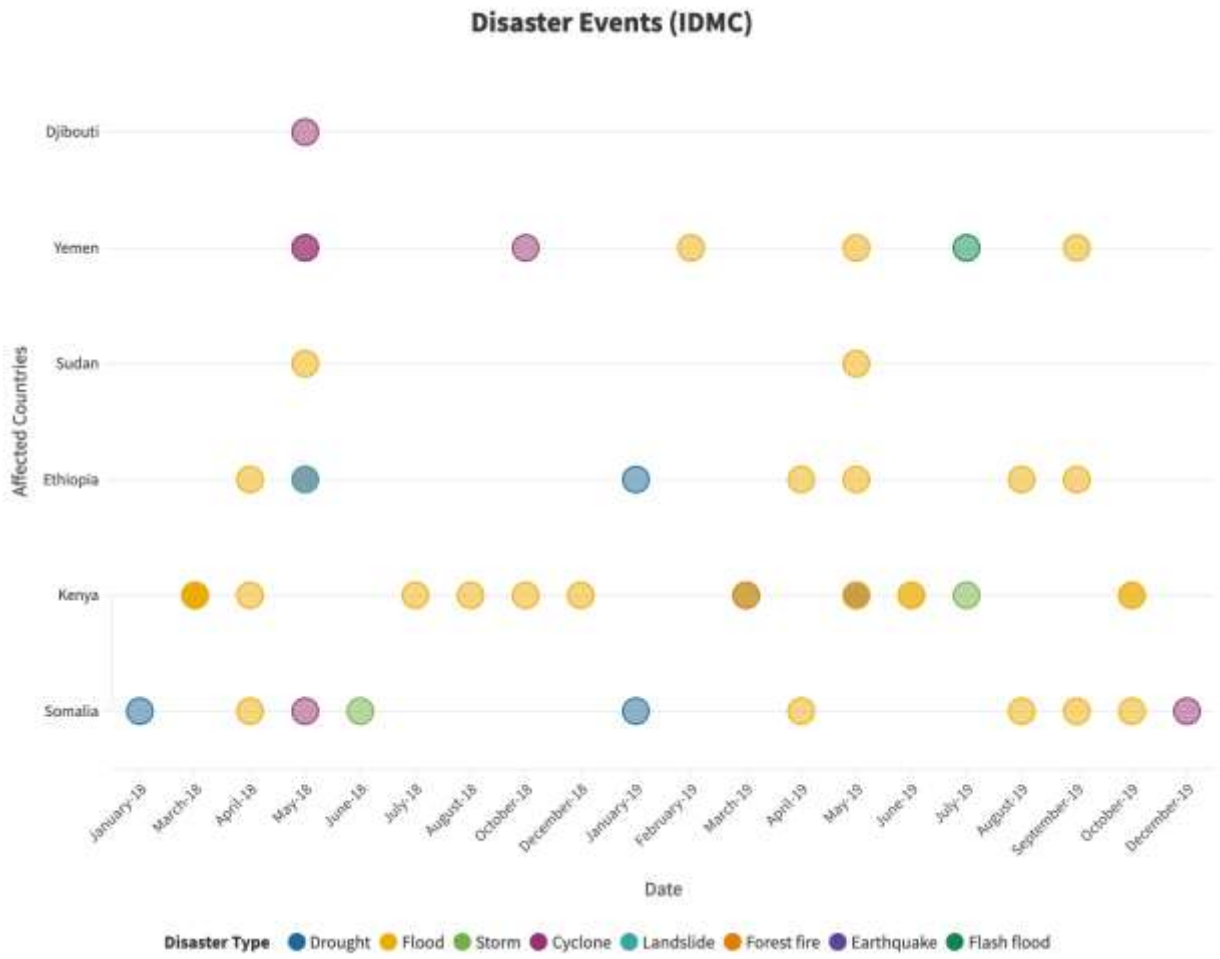


Figure 9. Source: IDMC (Disaster type labels were slightly modified for the purposes of this graphic). Figure created with Flourish

EhoA+Y region. Given the inextricable linkage of climate and natural disasters to livelihoods and local economies, we believed it critical within this study to consider economic-related migration as potentially climate-related migration.

[40] EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.

The previously discussed flooding experienced in 2018 across much of the region was preceded by a prolonged drought in 2017 and 2018 –a climate-related crisis that decimated much of the region's agricultural productivity.[41] This subsequently cascaded into threatened livelihoods, increased acute malnutrition, and likely contributed to communal violence.[42] One specific ramification of these droughts was the significant loss of livestock experienced by Somali pastoralists that has been directly linked to escalating food insecurity, sky-rocketing market prices, and resultant economic migration and/or internal and cross-border displacement.[43] These historical narratives correlate with the trends of disaster-related out-migration as seen in the time series analysis, however, the long-term effects of climate-related disasters on economic recovery may be better reflected in the economic-related out-migration trends.

The EHoA+Y's relationship between the environment and migration is even further complicated by the relationship between climate change, ethnical and political tensions, and even conflict. Growing bodies of literature [44] and plausible conceptual theories[45] link climate to economic distress, as discussed above, and heightened likelihood of conflict given resource scarcity. By looking at all-cause migration in the regression model, this study attempted to acknowledge these complexities and remove the potentially over-simplified categorization of single-cause migration flows. Notwithstanding efforts to explore the FMR and open-source environmental and disaster

[41] Anyadike, Obi. (2019, June 10). *Drought in Africa leaves 45 million in need across 14 countries.* https://www.thenewhumanitarian.org/analysis/2019/06/10/drought-africa-2019-45-million-in-need
[42] Ibid.
[43] Kibet, Robert. (2018, January 10). *Consecutive droughts spell disaster and hunger for Kenya in 2018*. The New Humanitarian. https://www.thenewhumanitarian.org/feature/2018/01/10/consecutive-droughts-spell-disaster-and-hunger-kenya-2018
[44] Abel, G. J., Brottrager, M., Cuaresma, J. C., & Muttarak, R. (2019). *Climate, conflict and forced migration*. Global Environmental Change, 54, 239-249.
[45] International Committee of the Red Cross (ICRC). (2020, July 9). *Seven things you need to know about climate change and conflict*. ICRC.

datasets to examine these complexities, the authors acknowledge the limitations of a secondary analysis of these data streams.

Further work could build on these methods, potentially incorporating conflict, economic, and likely COVID-19 datasets to create a more sophisticated spatial model of the drivers of out-migration in

the EhoA+Y region. While precipitation and ground temperature predominate the literature on climate and migration, additional climate variables such as vegetation indices or surface water area could be similarly explored. And as humanitarian data becomes increasingly standardized, granular, and universally codified, the incorporation of these migration-related data could produce more spatio-temporally precise studies and subsequently inform more targeted and tactical

programming. However, it is most critical to understand how the creation and provision of these outcomes improve decision-making in the field, and thus socialization of these methods and a user-centric approach to design and uptake is encouraged.

Conclusion

With increasingly complex drivers of human displacement and the specter of more and more devastating climate-related crises, there is a need to develop and explore methods to better understand these relationships. This study's utilization of spatial methods to examine FMR data and open-source environmental data emphasizes the spatio-temporal heterogeneity of all-cause migration in the EHoA+Y region between January 2018 and August 2020 and illuminates otherwise unseen spatial relationships between out-migration, climate variables, and previously documented, climate-related disasters. While some of these methods are primed to inform policy and programming to address migrating populations (e.g. spatio-temporal characterization of migration and flow types), much work is still to be done to explore the climate-conflict-migration nexus.