

Climate change, agriculture and international migration nexus: African youth perspective

Working Paper No. 324

CGIAR Research Program on Climate Change,
Agriculture and Food Security (CCAFS)

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RESEARCH PROGRAM ON
**Climate Change,
Agriculture and
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Abstract

Climate change is expected to contribute to the migration of tens of millions of people in the coming decades. While some migration will be caused by sudden-onset events, such as floods, the majority will be due to the long-term impact of climate change on livelihoods. Agrarian countries are particularly vulnerable to this climate change impact as the majority of their people depend on environmental resources and vulnerable ecosystems for their livelihoods.

This study explores the complex nexus between climate change, agriculture and international migration in East Africa, with a focus on the youth perspective. We provide an extensive review of the empirical literature on the climate-migration link. Based on regional climate modeling, we also show the trends of climate extremes for East Africa and provide climate projections for the coming decades. Our study also examines the quantitative relationship between climate variables and migration stock for case study countries.

Results from our climate model show that the East African region will experience longer and more frequent droughts than those associated with the current climate, suggesting that agricultural livelihoods in East Africa will become more vulnerable in the coming decades. The region experienced significant growth in outmigration in the past few decades and climate change is likely to accelerate this migration trend. Our quantitative analysis provides suggestive evidence to support this hypothesis. The analysis shows that a higher number of average dry days for a country is positively correlated with higher stock of emigrants from that country.

The prospect of youth international migration from East Africa is high and likely to increase with climate change. East Africa's youth population is not only the highest in the continent, but is more likely to be unemployed, less encumbered with family responsibilities and have more education than the previous generation. All of these factors support the likelihood of higher youth migration in the context of climate change.

Keywords

Climate change; migration; youth

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Acronyms

CHIRPS	Climate Hazards Infrared Precipitation Station
CMIP5	Coupled Model Intercomparison Project
CSA	Climate-smart agriculture
EC-EARTH	European Community Earth-System Model
FAO	Food and Agriculture Organization of the United Nations
GCM	Global Circulation Model
GDP	Gross domestic product
GHoA	Greater Horn of Africa
GHG	Greenhouse gas
HadGEM2	Hadley Centre Global Environment Model Version 2
ICTP	International Centre for Theoretical Physics
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
PDSI	Palmer Drought Severity Index
PSNP	Productive safety net program
RegCM4	Regional climate model
RCP	Representative concentration pathway
SPI	Standard Precipitation Index
SSA	Sub-Saharan Africa
UNDESA	United Nations Department of Economic and Social Affairs
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank
WMO	World Meteorological Organization

Introduction

Human activities are estimated to have caused approximately 1°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C (IPCC 2018). According to the United Nations Framework Convention on Climate Change (UNFCCC), while climate models project robust differences at various levels of confidence in regional climate characteristics, there is an overwhelming agreement that, if warming continues to increase at the current rate, global warming is likely to reach 1.5°C, if not beyond, between 2030 and 2052 (IPCC 2018). Among many other potential impacts, it is estimated that, globally, an average warming of 1.5°C or beyond raises a number of risks, including heatwaves, heavy rainfall events, crop productivity decline, reduction in water availability, undernutrition and habitat loss (IPCC 2018).

One of the expected consequences of these massive changes in the climate is an unprecedented level of human migration. Climate change is anticipated to influence human mobility in all regions of the world - although the specific types of impact and magnitude depend on both biophysical and socio-economic factors (Piguët and Laczkó 2013, IPCC 2014a). Existing evidence shows that climate-induced migration is already taking place across the world, (Foresight 2011, Ionesco et al. 2016, Rigaud et al. 2018) making it imperative to learn more about and plan for this migration. Unplanned, large-scale migration at breaking point for the affected communities creates humanitarian crises, logistical complications (Foresight 2011) and, potentially, political crises, especially if most of the migrants are working-age youth.

Climate change will hit poor countries and communities relatively harder due to their limited coping and adaptive capacity across sectors and the reliance on environmental resources and vulnerable ecosystems as a source of livelihoods in poor countries (WRR 2017). At a household and individual level, poor people might be heavily affected by climate change even when impacts on the rest of the population are limited (IPCC 2018). Regions that are dry are expected to become dryer and experience extreme heat events more frequently, (Trenberth et al. 2014) impacting livelihoods of the resource-poor population living in these countries.

Most of the world's poor live in agriculture-dependent countries in Africa and Asia, and climate change is expected to have strong negative effect on agriculture (Ray et al. 2019). While extreme weather events such as floods, cyclones and drought are visually striking, the long-term, negative effects on production, productivity and risk exposure may be more damaging for agriculture-dependent countries and communities. For example, farmers' access to agricultural land could decline due to landslides, land degradation, flooding or salination. At the same time, deterioration in

the quality and availability of forests, water and other ecosystems could result in decreased farm productivity, fishing and other related activities – impacting food security.

The increased risk of climate change contributes to large scale migration by exacerbating existing migration drivers. This requires a concerted effort among countries to minimize unplanned displacements and to facilitate safe and orderly migration. Recent international conventions and agreements recognize and reflect this need for international cooperation and coordination. For example, following the request from the 2015 Paris Agreement, the Executive Committee of the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts established a task force that can develop recommendations for integrated approaches to avert, minimize and address displacement related to the adverse impacts of climate change. The 2016 New York Declaration for Refugees and Migrants (UNHCR 2018) also highlights the importance of a coordinated response. The declaration emphasizes that large movements of refugees and migrants have political, economic and social consequences that cross all borders, demanding global approaches and solutions (UN 2016). Similarly, the UN's 2030 Agenda for Sustainable Development calls for member countries to facilitate orderly, safe, regular and responsible migration and mobility of people, including the implementation of planned and well-managed migration policies. This study aims to contribute evidence for the need to translate these initiatives into effective policies. The study assesses the nexus among climate change, agriculture and international migration in eastern Africa. While the link between environmental shocks and internal migration in Africa has been relatively well researched, (Gray and Mueller 2012, Kubik and Maurel 2016, Mastorillo et al. 2016) there is not much work on the impact of climate change on international migration. This study will help to fill this gap.

Agriculture is the main source of livelihoods in Africa, including in East Africa (WB 2019). Across the continent, the sector contributes around 60 percent of jobs and about 25 percent of gross domestic product (GDP) (African Development Bank 2016). There is sufficient evidence to suggest that African ecosystems are already being affected by climate change, that these changes will grow worse in the future, and that the agricultural system is becoming more vulnerable over time (IPCC 2014b).

Even though most African countries depend on rain-fed agriculture, and as such are vulnerable to climate impacts, the region has not attracted as much research as other vulnerable regions. For example, the Intergovernmental Panel on Climate Change (IPCC) (2014c) highlighted that current climate adaptation knowledge in this region relies heavily on case studies. Similarly, there is a considerable amount of uncertainty in climate projections for East Africa. This is partly due to the

coarse resolution of global climate models which do not reliably capture local processes and features, such as the complex topography of the region (Yang et al. 2015, Rigaud et al. 2018).

This study contributes to filling these gaps by studying the complex nexus between climate change, agriculture and international migration in East Africa. The study provides an extensive review of the existing literature on the climate-migration link and a conceptual framework that shows the different channels through which climate change can lead to migration in East Africa. The study employs regional climate models to show trends of climate extremes, such as drought, in East Africa and provides climate projections in the coming decades. Using combined climate model estimates for dry days and migration data from the United Nations Department of Economic and Social Affairs (UNDESA) (UNDESA 2017a), the study also quantitatively analyzes the relationship between climate change and migration in East Africa. As this study is especially interested in the youth dimension, it highlights findings that are particularly relevant for the region's youth.

Scope and limitation of the study

The study covers eight East African countries, including Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan, Tanzania and Uganda. As the focus of the study is on international migration, the data used in the quantitative analysis is based on stock of international migrants from these eight countries as reported by UNDESA (2017a). In this study, we define youth as those between the ages of 15-34, as suggested by the African Youth Charter (AU 2006).

The main limitation of this study is availability of age-disaggregated data. Most of the studied countries do not have national-level international migration data for use in this analysis. While the UNDESA data provides uniformly measured international migration data for all the case study countries, the data have three basic weaknesses that limit the level of quantitative analysis that can be conducted: i) given that the data collection is based on stock of legally registered migrants in the destination countries, it misses irregular migrants, ii) it is not disaggregated by age, hence separate youth international migration figures are missing, and iii) while the data covers 27 years (1990-2017), it is reported in a five year gap. With only eight countries in the sample, this low frequency data means our quantitative analysis is limited by the relatively low sample size.

The study uses regional climate modelling that performs better than the global model in simulating key processes relevant for regional extremes. However, given the limited scope of the study, the analysis did not disaggregate within the country. The climate variables in the drought analysis are averaged at the country level rather than over specific drought prone areas or hotspots of the country. Similarly, the climate analysis was based on annual data instead of crop growing seasons. Despite these limitations, it is expected that the climate trends and forecasts from the regional climate models capture the real trend very well.

Climate change - migration link: Conceptual framework

The problem of establishing causality

Migration is a growing and complex global phenomenon. Although there is a consensus among researchers that climate change is expected to significantly influence human mobility, (Foresight 2011) empirically documenting the link between climate change and migration is not straightforward. For example, the widely cited projections on 'climate refugees' (Myers and Kent 1995) is challenged by many researchers because it suggests that all those vulnerable to climate change, including youth, will migrate, which is not necessarily the case (Foresight 2011). In addition to climate, a multitude of factors influence migration decisions including personal, political, economic and environmental conditions. The complexity of migration decision-making as a whole and the difficulties of causally linking climate change with specific migration decisions is acknowledged and extensively debated in the literature (Tacoli 2009, Warner et al. 2010, Black et al. 2011, Foresight 2011, Maystadt and Mueller 2012, Nicholson 2014, Bettini 2017, Sudmeier-Rieux et al. 2017). Recent work on the topic provides a more useful framing of the climate change and migration relationship which focuses on how climate change influences the already acknowledged drivers of migration (Foresight 2011, Rigaud et al. 2018).

Conceptual framework: Climate change, agriculture and migration

The obvious link between climate change and migration is through displacement caused by extreme weather events, such as cyclones, hurricanes, drought, etc. Climate change, however, also interacts with other drivers of migration, mainly social, economic, political, environmental and demographic (Perch-Nielsen et al. 2008, Warner et al. 2010, Black et al. 2011, Foresight 2011, Rigaud et al. 2018).

Climate change, in addition to causing displacement from extreme weather events, interacts with social, economic, political, environmental and demographic drivers to create even stronger migration pressure.

These interactions will create an even stronger migration pressure, although the link may not always be obvious. For example, climate change may accelerate political migration due to an increase in conflict caused by resource competition among individuals and groups (Foresight 2011). Considering these indirect interactions, this study proposes a conceptual framework that discusses the main channels through which climate change could trigger migration for agriculture-dependent countries and communities (see Table 1 for major links and references that show empirical evidence for each of the links described).

For farm households, the main effect will be climate change's effect on agricultural productivity and agricultural risk that could impact food security. Climate change is expected to increase landslides,

land degradation, salination and a reduction in the quality and availability of complementary natural resources such as forests, water and other ecosystems. These changes will diminish the size, suitability and productivity of farmland that is the basis for agricultural livelihoods, eventually pushing farmers and the youth to migrate. For example, a study from Nepal shows that migration increases with perceived decline in land productivity and vegetation cover (Massey et al. 2010).

Climate change is also expected to increase rainfall variability and causes frequent episodes of extreme weather events, such as drought or floods. This will increase production risk and the livelihood vulnerability, eventually leading to more migration. Large panel data studies from Indonesia, Pakistan and Latin America suggest that an increase in temperature and rainfall variability influences long-term migration patterns more than natural disasters (Bohra-Mishra et al. 2014, Mueller et al. 2014, Thiede et al. 2016). Extensive empirical evidence on agricultural livelihoods shows that migration is one of the most common adaptation responses to environmental shocks and the reduction of agricultural income. For example, a study assessing the effects of drought on population mobility in Ethiopia shows that land-poor households, especially youth, are the most vulnerable to this climate extreme (Gray and Mueller 2012). As climate change is expected to create more environmental shocks in the coming decades, we are likely to see increased migration.

The effects of climate change on agricultural production and productivity is not limited to farmers in rural communities. What happens in the agricultural sector will also have significant effects on non-farm households through local and urban labor markets, as well as its effect on the national economy. For example, a decline in production and productivity of agricultural activities will push more farmers, especially young farmers, away from farming into non-farm wage employment. This move will eventually lead to international migration as the increased labor supply depresses wages for unskilled labor (Maurel and Tuccio 2016). A slowdown in the agricultural sector in these agriculturally-dependent economies will also result in slower economic growth and, overall, fewer economic opportunities because of the linkage between agriculture and the rest of the economy (Dell et al. 2012).

Table 1. Impact of climate change on agricultural livelihood and its potential effect on youth migration.

Channel of influence	Climate change	Impact on agricultural livelihoods	Expected indirect impact on youth migration	Empirical evidences showing migration link (examples)
Farmland	Decrease in availability of suitable farmland due to landslides, degradation, flooding, salinization etc.	Reduction in agricultural production capacity	Increased migration	Massey et al. (2010)
Ecosystem	Deterioration in the quality and availability of natural resources, including forests, water and other productive ecosystems, leading to resource scarcity and local competition.	Reduction in household's agricultural yield	Increased migration	Massey et al. (2010), Wrathall and Suckall (2016)
Production risk	Increase in rainfall and temperature variability and frequent, extreme events.	Increased production risk	Increased migration	Gray and Mueller, (2012), Bohra-Mishra et al. (2014), Mastrorillo et al. (2016)
Local labor market	Rural wages are reduced as many farmers resort to hiring out their labor due to a decline in their crop productivity. Pressure to migrate to urban areas increases. In addition, as food prices increase due to productivity decline, real wages decline.	Decline in nominal and real wage	Increased migration	Mueller and Quisumbing (2010), Jayachandran (2006)
Macroeconomic condition	Repeated extreme weather events and ecosystem deterioration negatively influences economic growth and reduces opportunity for citizens.	Reduced employment and income earning opportunity	Increased migration	Dell, Jones and Olken (2012)

Empirical literature on climate-induced migration

The scale of the problem

Assigning specific numbers to the magnitude of climate migration is controversial. The estimated 'climate migrant' or 'climate refugee' projections cited in various papers and reports, including the influential Stern Report (STERN 2007) and Human Impact Report (GHF 2009) are criticized as speculative and methodologically unsound (Black et al. 2011, Foresight 2011, Gemenne 2011, Jakobeit and Methmann 2012, Bettini 2017). Many of these projections also build-on or refer to a single publication from 1995 (Myers and Kent 1995) that is itself criticized for methodological weakness (Foresight 2011).

As previously discussed, the main challenge in assigning a specific number to climate migrants arises from the fact that migration has many drivers. While displacements caused by extreme weather events are easier to account for and attribute, such displacements account for only a small share of migration. Despite this, due to the short- and long-term effects of climate change, the scales provide some suggestive evidence for the linkage between climate change and migration. For example, in 2017 alone, about 19 million people were displaced by sudden-onset disasters within their own country, and between 2008 and 2016 an estimated 228 million people were displaced by disasters (IOM 2018). This does not include cross-border migration for which data is not available (IOM 2018). Although many disaster-related displacements are presumed to be temporary and internal, there is increasingly more evidence to suggest that, for individuals and communities that are economically and socially vulnerable, the temporary displacement due to climate-related risks can easily turn to permanent migration (IPCC 2014c). Moreover, as discussed above, climate change will trigger more and longer-term migration through its impact on other drivers of migration, even if it is not easy to identify its separate effect.

Climate change and international migration

Internal versus external migration

Most climate migration in developing countries is expected to be movement within the same country, often from rural to urban areas (Rigaud et al. 2018). This is partly because the effect of environmental changes is stronger and more direct on agricultural activities, which are typically located in rural areas (Marchiori et al. 2012). Massive internal migration poses a significant challenge for any country, but it can be especially demanding for developing countries that often suffer from poor infrastructure, weak institutions and binding financial constraints. It is likely that such displacements spill into neighboring countries and could create transboundary problems involving young climate migrants. Moreover, national and international migration is essentially interlinked. A rapid increase in internal youth migration, especially from rural to urban areas, is likely to increase the level of international youth migration due to pressure on the urban wage (Marchiori et al. 2012).

Empirical literature on the impact of climate change on international migration

The impact of climate change on international migration is not well researched, especially youth migration. This is partly due to the challenges of attribution discussed earlier and the lack of detailed and reliable data on international migration, particularly from developing countries. The limited evidence on the link between international migration and climate change is often based on the analysis of macro-level cross-country data that exploits the information available from developed countries as receiving nations. These studies often use temperature and precipitation to assess the correlation between variations in these environmental factors and migration flow. Cai et al. (2016) used 30 years of bilateral international migration datasets for 163 origin countries and 42 destination countries. They tested the hypothesis that climate change affects international migration through its effect on agricultural livelihoods. They estimated a country-pair fixed-effects regression model that links origin country weather variations to its international out-migration. Interaction terms between weather and agricultural dependence are included in the model to assess the agricultural link. The study found a positive and statistically significant relationship between temperature and international out-migration. Supporting their hypothesis, the results show that this relationship holds for agriculture-dependent countries. The study also shows that extreme heat and heat stress are correlated with both lower crop yields and higher flows of out-migration. The GDP of agriculture-dependent countries are also more negatively affected by higher temperature than non-agriculture-dependent countries (Cai et al. 2016).

Another study, by Backhaus et al. (2015), also found a similar, positive association between temperature and migration. In this study, Backhaus et al. (2015) applied a gravity model on panel migration data from 142 migrant sending countries for the period 1995 to 2006. They found a positive correlation between temperature and migration, and similar to the study by Cai et al. (2016), the Backhaus et al. study also shows that the positive correlation between migration and temperature holds for agriculture-dependent countries. There are more studies that demonstrate similar, positive correlations between temperature and international migration based on cross-country studies (Afifi and Warner 2008, Naudé 2009). There are, however, very few studies that explore the linkages between environmental change and international migration based on time-series or panel data at a national level. Two studies on Mexico – US migration show that a decrease in precipitation is significantly associated with US-bound migration, especially for dry Mexican states (Feng et al. 2010, Nawrotzki et al. 2013). Feng et al. (2010) went further to provide an estimate of the number of future migrants due to climate change. The study reported that, at a higher global warming scenario, more than six million adult Mexicans will emigrate by the end of the century as a result of agricultural productivity declines alone, with most of these migrants likely to be younger and productive members of the Mexican population.

To summarize, the research exploring the link between climate change and international migration found that changes in temperature and precipitation are closely correlated with migration flow. While there is some variation in the findings, the research is consistent in showing a stronger impact of climate change on agriculture-dependent countries and communities. There is, however, a lack of research analyzing the relationship between climate change and international migration for Africa and none focuses on the relationship's impact on youth international migration.

The age and gender dimension of climate-induced migration

In 2017, there were 258 million people in the world residing in a country outside of their country of birth (UNDESA 2017a). Youth are overrepresented in migration relative to their share in the total population. For instance, the estimated number of young migrants (aged 15 to 24) rose from approximately 22 million in 1990 to 31 million in 2019. In 2019, young migrants accounted for 11.4 percent of the total migrant population but only 5.1 percent of the total population of all ages (UNDESA 2019). Globally, there is more youth migration from and within Africa. The number of emigrants between 15-30 years of age accounts for a quarter of the international migrant stock and one-third of international migrants in Africa. When expanding the age group to include those between the ages of 10-34 years old, the share of adolescent and youth migrants in Africa increases to 51 percent (UNDESA 2017b).

Men are slightly more likely to migrate than women. In 2017, women accounted for 48.4 percent of all international migrants worldwide and 46.8 percent of international migrants in Africa (UNDESA 2017a). While there is a dearth of literature on the specific implications of climate change on international migration for youth and women, evidence from related literature suggests that the youth and women may be affected differently. In the next two sub-sections, we highlight some of the issues relevant for female and youth international migration as it relates to climate change.

Climate change and international youth migration

Although the youth may not have a higher level of exposure to climate change compared to other sections of society, lessons from labor migration research suggest that the youth, often in the age group of 15-30, are more likely to migrate in search of

Young people are more likely to migrate in search of a better livelihood.

better livelihood (Lipton 1980, De Haan 1999, Castles et al. 2013). As discussed above, climate change is likely to compromise the livelihoods of youth in agriculture-dependent countries. Climate-induced environmental change is going to reduce both the quality and quantity of land available for farming, resulting in fewer livelihood sources for aspiring young farmers and other youth joining the agricultural labor market. Since youth are often unencumbered by family and social responsibilities, they are more likely than other members of the community to migrate in search of better livelihoods. The younger population, including those in eastern Africa, generally have better information and education when compared to previous generations, increasing the likelihood of climate-driven international migration from the continent.

Climate change and female migration

Climate change is expected to have a disproportionate impact on women in developing countries due to their culturally assigned roles, social positions, limited control over resources and other socio-economic vulnerabilities (Arora-Jonsson 2011, Eastin 2018). For example, a decline in the availability of water

“Climate change is expected to have a disproportionate impact on women in developing countries.”

due to climate change is expected to increase the amount of time and effort women spend in collecting drinking water for the family. It is not obvious, however, whether women are more or less likely to migrate due to climate change. Women and men differ both in the pressure they experience from climate change and in terms of their adaptive and outmigration capacities. On the one hand, a reduction in the availability of suitable agricultural land and other environmental resources reduces women’s absolute and relative access to economic resources, even more than before, increasing their incentives to migrate. On the other hand, the cultural constraints on women’s mobility, their lack of information and resources for international migration and their socio-cultural obligation to less mobile members of the family will make women less able to out-migrate.

Women may also be differently affected by the migration experience itself (Cannon 2002, Chindarkar 2012, Antman 2013, Zhang 2018). Since women in developing countries often have fewer skills and less education, migrant women are less likely to secure formal sector employment compared to migrant men. When migrating as a family, the nutritional status of poor women may deteriorate further as they prioritize their children and men of the household (Cannon 2002). In the cases where the rural household responds to environmental stress by sending out male members of the household to urban areas or abroad, the women who stay behind experience a significant increase in workload in the short run as they are forced to cover the household chores, child rearing and farm activities. Women, particularly single women, are also more likely to be exposed to trafficking and sexual abuse during international migration.

Trend and forecast of droughts over East Africa

Modeling droughts in eastern Africa

The livelihood of populations in many parts of Africa is strongly tied to subsistence and rain-fed agriculture. Climate extremes, such as frequent droughts and water stress, account for widespread food insecurity and failures in several key sectors (e.g. agriculture, energy, water

“East Africa has recently suffered from repeated drought, floods and other disasters that result in significant out-migration.”

resource management) that contribute to the regional economy. For instance, the 1974-1975 drought in Sub-Saharan Africa (SSA) caused 325,000 deaths in the Sahel, while the 1984-1985 drought in SSA led to 450,000 deaths in Ethiopia and Sudan alone (Guha-Sapir et al. 2004). Hence, improved understanding, proper assessments and predictions of extreme climate events in the context of climate change are of paramount importance. As a result, several observational and modelling studies have been conducted over different regions of the globe to document the characteristics of extreme events, such as drought in current climate conditions and to assess the impact of global warming on future drought occurrences, severity, duration and patterns (Ntale and Gan 2003, Blenkinsop and Fowler 2007, Sheffield and Wood 2008, Liu et al. 2012, Sienz et al. 2012, Zeleke et al. 2017). However, there are limited detailed climate modeling studies using high-resolution regional climate models in East Africa. The few existing studies are either on current conditions (Viste et al. 2013, Zeleke et al. 2017) or employ coarser resolution global climate models (Gizaw and Gan 2017).

Although global climate models are based on well-established physical principles and have been demonstrated to reproduce several aspects of observed large-scale climate features, they need proper evaluation to assess climate change at regional and local scales. This is because global models have a limited capacity to simulate key processes which are relevant for the generation of regional extreme events due to their coarse resolution, missing processes or parameterization of sub-grid scale processes (Brasseur et al. 2017). It is also important to understand the role of local to regional scale processes, such as land-atmosphere interactions, orographically enhanced precipitation, and convective storms, in modulating the intensity and evolution of regional extreme events. Such meso-scale processes are better represented and simulated by high resolution regional climate models. In fact, numerous studies (e.g. Jung et al. 2012) have been carried out to assess the level of performance of high-resolution regional climate models, demonstrating that, while large-scale mean climate features are reasonably simulated by coarser resolution models, fine-scale resolution regional models are better in simulating convective

events, surface induced precipitation or diurnal cycles of precipitation. Wehner et al. (2010), for instance, highlighted how the increase in model resolution led to improved simulations of extreme precipitation over land using such an approach. It must be clearly noted that observed extremes, as well as the trend in extremes in the current climate, are not well simulated by a typical coarse resolution global climate model (Kharin et al. 2007).

One of the objectives of this section is, therefore, to characterize the drought patterns and the frequency of extreme dry days in the current climate using observations and high-resolution regional climate model simulations to avoid the aforementioned shortcomings of coarse-resolution global climate models. We are also interested in investigating the characteristics of these extreme climate events, such as droughts, and how they are projected to change by analyzing the current and future climate simulations under the realistic worst-case scenario for greenhouse gas (GHG) emissions using the Representative Concentration Pathway (RCP) 8.5 for East Africa. This section is focused on producing climate modelling data for the region that highlight past and future trends in extreme events that are directly relevant for agriculture. The relation between occurrence of extreme events in each country and its impact on migration will be investigated in the next section.

Domain, data, model and method

Domain, observation data and model simulation

Domain: The study area considered covers the eastern part of Africa, often called the Greater Horn of Africa (GHOA), ranging between 20°S to 20°N as shown in Figure 1. This includes Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan, Tanzania and Uganda. The region includes a complex topography with elevation ranging from 200 meters (m) below sea level in Ethiopia's Afar Depression to 5895 m above sea level at the top of Mount Kilimanjaro in Tanzania. It is also considered drought prone as a significant portion of the area is semi-arid, in addition to the erratic nature of rainfall amount, distribution and pattern in the region. The rainy season varies considerably across the region due to the movement of the Inter-Tropical Convergence Zone (ITCZ) and the underlying complex topography of the region. As a result, the northwestern part of the domain, including western Ethiopia, Eritrea and Sudan, receives rainfall from June to September, whereas countries in the equatorial and southern part of the domain receive rainfall mainly in the spring, from March to May, and autumn, from October to December. Other parts of the region, such as northeast Ethiopia, receive rain during the spring and summer seasons (Segele and Lamb 2005).

Observation Data: High resolution data for daily precipitation observations over the GHOA was obtained from the climate hazards infrared precipitation station (CHIRPS) (Funk et al. 2015). CHIRPS is constructed by merging local station data and infrared satellite estimated precipitation, making it an attractive option for data sparse regions, such as the GHOA. Although the data is available at higher resolution and for a longer period, the sub-set data used here covers the time period from 1983 to 2016 and is interpolated onto a 0.250 grid resolution.

Model simulations: In this study, we also used simulated precipitation data for current (1983-2005) and future (2077-2099) periods and scenario analyses at a spatial resolution of 0.24 degrees, using the International Centre for Theoretical Physics' (ICTP) regional climate model (RegCM4) (Giorgi et al. 2012) driven by two of the fifth phase of the Coupled Model Intercomparison Project (CMIP5) global models, namely the Hadley Centre Global Environment Model Version 2 (HadGEM2) and a European Community Earth-System Model (EC-EARTH).

Method: Quantifying regional climate extremes in East Africa

Several indices have been devised to quantify climate extremes, particularly for droughts (Dai 2011). These indices range from those that consider only precipitation, to more complex methods that consider

a water balance approach using precipitation, evapotranspiration and antecedent soil moisture. In this study, we utilize two different meteorological indices from the first category (i.e. using only precipitation dataset) to characterize historical and future droughts over East Africa. The first one is the number of dry days, which can be computed annually or for a specific growing season as it reflects the overall condition of extreme climate conditions for rain-fed agriculture. We define a dry day when the cumulative daily precipitation values are less than 1mm. The frequency of dry days is computed on an annual basis. These analyses can indicate if the frequency of dry days within the growing season is substantially different from year-round frequencies in the region.

The second index is the Standardized Precipitation Index (SPI) (McKee et al. 1993), recommended by the World Meteorological Organization (WMO) to characterize long-term meteorological droughts around the world (Hayes et al., 2011). This is a relatively simple index based on precipitation data alone to measure the precipitation deficit (drought) or excess rainfall (flood) (Seiler et al. 2002). To compute the SPI, monthly time series of precipitation are fitted to a gamma distribution. SPI values are estimated as a transformation of the cumulative probability to a standard normal value with a zero mean and a variance of one. SPI can, therefore, be considered a measure of standardized departure from the empirical rainfall probability distribution function. Various thresholds have been suggested to identify drought (McKee et al. 1995, Komuscu 1999, Agnew 2000). According to McKee et al. (1995), an SPI value of less than -2 indicates an extreme drought, whereas a value of less than -1 (between -2 and -1) indicates a moderate drought. Even though the SPI relies solely on monthly precipitation values, it has performed well over the eastern African region as demonstrated by Ntale and Gan (2003). Another advantage of SPI is that it can be calculated over different time scales to allow for the interpretation of drought from a monthly to multiyear scale. In this study, year-long drought (SPI12) is computed at a spatial scale of one degree to represent long-term meteorological drought patterns in East Africa. We will focus on the occurrence of drought, defined as the total number of drought events below -1.5 (i.e. for severe and extremes ones) in the entire study period (i.e. past, present and or future periods).

Drought in eastern Africa: Modeling results

Present-day climate patterns

The number of dry days is important for the estimation of meteorological drought. Figure 1 shows the climatological mean number of dry day frequency for annual (a) and summer (b) seasons for the 1983-2005 period. For the GHoA region, dry-day occurrences seem to be affected by the elevation in both the annual and summer seasons. The climatological dry-day frequency exhibits a remarkable spatial pattern with high values over lowlands

(e.g. Somalia, Djibouti northern Kenya and south-eastern Ethiopia) and lower values over central (e.g. Congo) and eastern Africa (e.g. Ethiopian) highlands (Figure 1).

“Quantitative analysis shows that international migration in eastern Africa is correlated with drought. For every single day increase of annual dry days in a country, 3,400 emigrants can be expected from that country.”

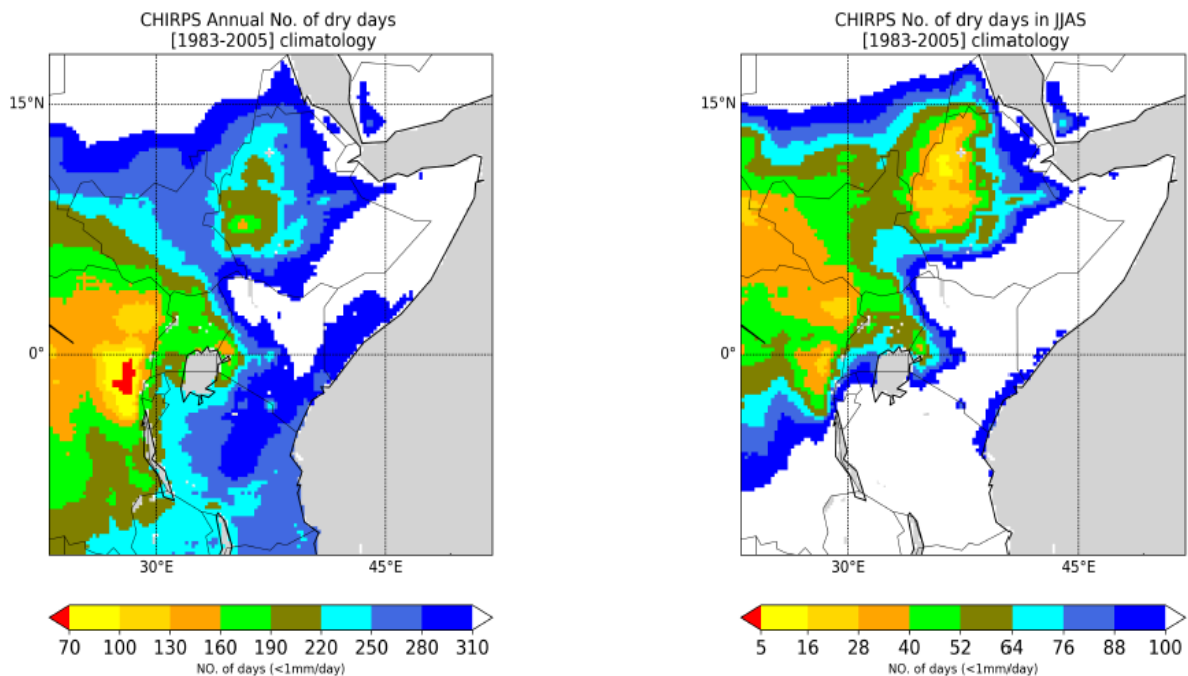


Figure 1. Frequency of annual (a) and summer (b) dry days from CHIRPS dataset.

The Global Circulation Model (GCM), driven by the RegCM4 simulation, reproduced the overall spatial patterns of the observed dry-day frequency both on an annual basis and during the summer season (Figure 2). As expected, the regional model simulations show few numbers of dry days over climatologically wet regions and a high number of dry days over semi-arid and desert regions. The high-

resolution simulations show that the spatial pattern and magnitude of precipitation extremes are much closer to the observed values as noted in other studies (e.g. Wehner et al. 2010).

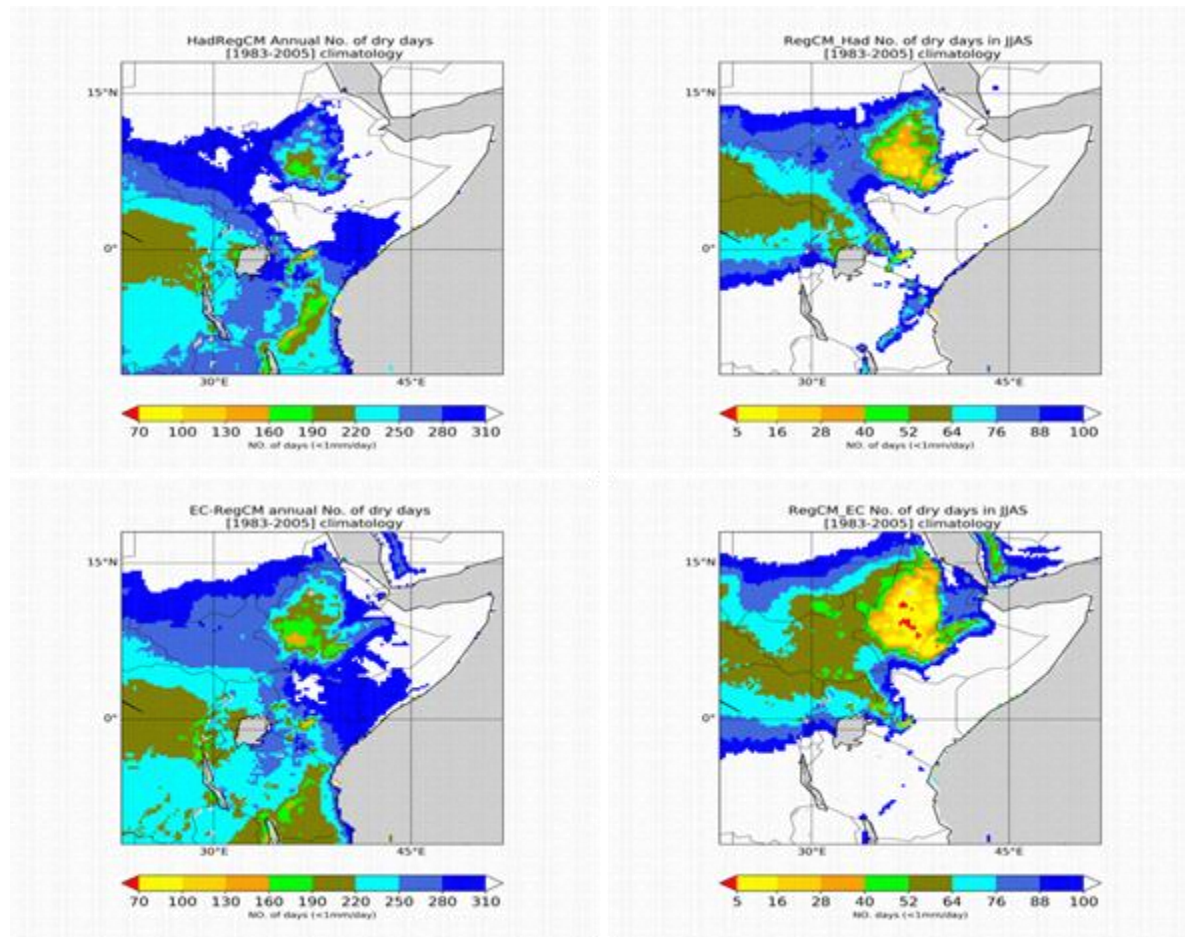


Figure 2. Simulated climatology of annual (left) and summer (right) number of dry days from RegCM- HadGEM2 (top row) and RegCM4-ECEARTH (second row).

It should be noted that minor biases are unavoidable, even in regional model simulations, despite the significant improvements in capturing the local and regional spatial scale events. For example, RegCM4 simulations show an overestimation of annual dry days over northeast Ethiopia. It must also be noted that extreme precipitation estimates from observational data are only reliable for regions with dense station networks like those near cities and densely populated areas.

Figure 3 shows the occurrence of severe to extreme droughts based on the definition of SPI using observational and present-day simulation data. Results based on the CHIRPS precipitation data suggest that severe and extreme droughts frequently occur over central Tanzania, regions bordering Sudan and Eritrea, Ethiopia and northern Somalia. It is important to note that SPI is a normalized index and, hence,

the frequency of drought is not influenced by the level of aridity of the region. Analysis of the simulated drought generally suggests the models reproduced some aspects of the observed drought pattern. In particular, the regional model simulations are able to reproduce the prevalence of drought occurrences over northern Somalia, southern Ethiopia and Tanzania as demonstrated in Figure 4. There are, however, important differences between the observed and simulated drought patterns. For instance, the frequency of severe to extreme droughts over Tanzania and the region near the border of Sudan and Eritrea may have been underestimated to a limited extent.

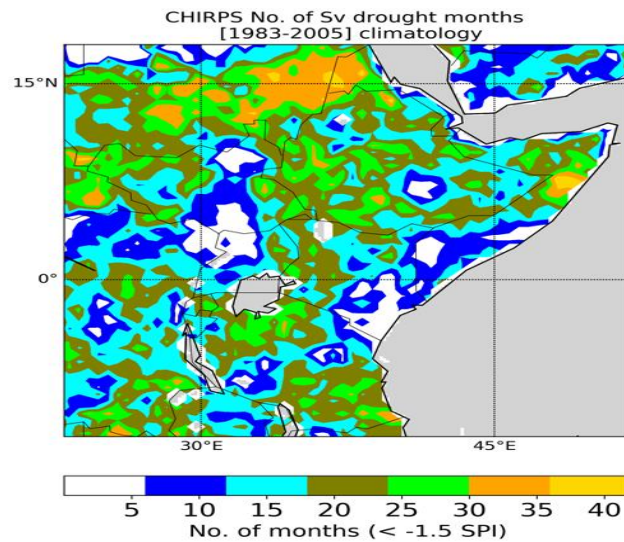


Figure 3. Occurrence of severe to extreme drought (number of months for which $SPI_{12} < -1.5$), observation data

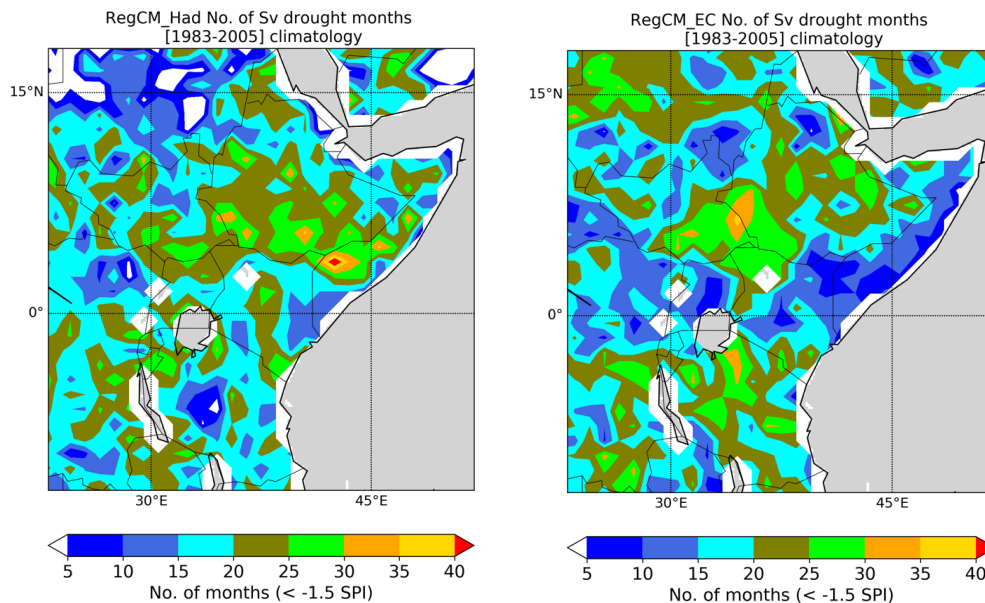


Figure 4. Occurrence of severe to extreme drought (number of months for which $SPI_{12} < -1.5$) from regional model simulations for the 1984-2005 period

Future projections

This study also investigates how droughts are projected to change under future climate scenarios. The spatial distribution of the projected changes in the climatological mean of the dry-day frequency in future climate is displayed in Figure 5. Both simulations (Figure 5a and Figure 5b) consistently project an increase in the frequency of growing-season dry-days throughout the regions where summer is the main rainy season under the RCP 8.5. The increase in the EC-EARTH driven RegCM4 simulation (Figure 5b) is, however, not uniform across the region or the national and sub-national level. For example, the simulation shows less impact over the main parts of the Ethiopian highlands but indicates an increasing intensity along the peripheries within Ethiopia. Since the region is already experiencing food insecurity under the current climate, the projected increase in dry days suggests the potential for higher, future vulnerabilities in this region due to further climate warming.

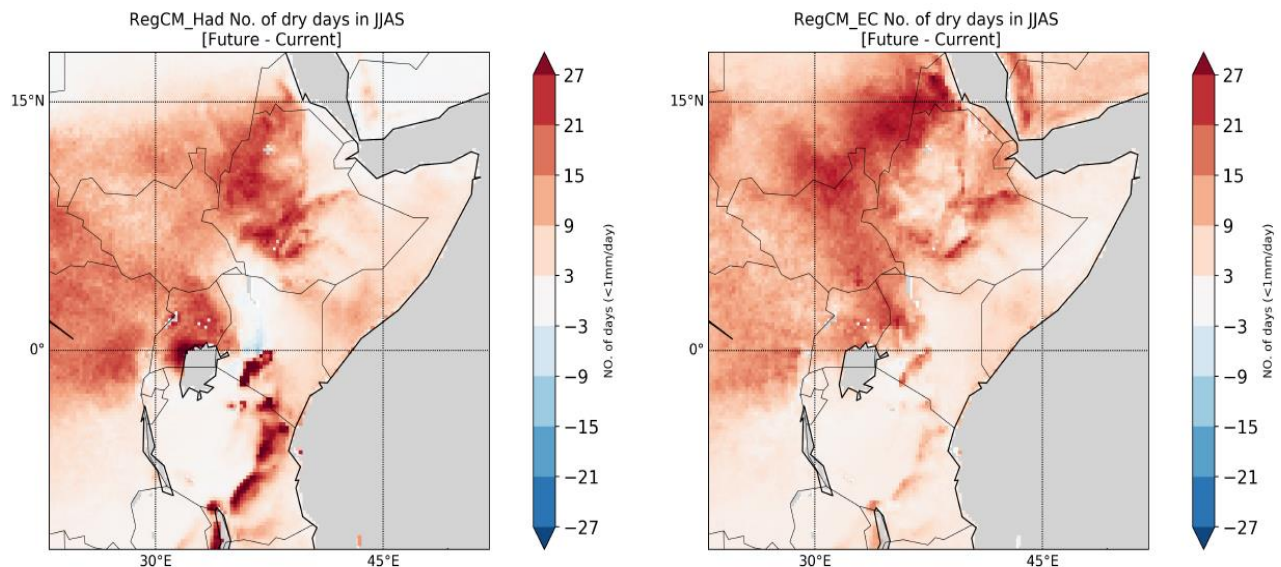


Figure 5: Projected changes in frequency of dry days in the late 21st century (2077-2099) relative to current (1983-2005) from RegCM-HadGEM (left, Fig. 5a) and RegCM4-ECEARTH (right, Fig. 5b) simulations.

The spatial pattern of the change in the occurrence of severe to extreme drought episodes in the late 21st century is given in Figure 6. Unlike the number of dry days, which measures short-term droughts, the frequency of long-term extreme droughts, measured by SPI12, does not show a significant increase in droughts in the future, even though this measure is increasing and still poses a substantial threat to the region's agricultural productivity and livelihoods. This implies that climate change is expected to affect the frequency of droughts differently over different regions within East Africa.

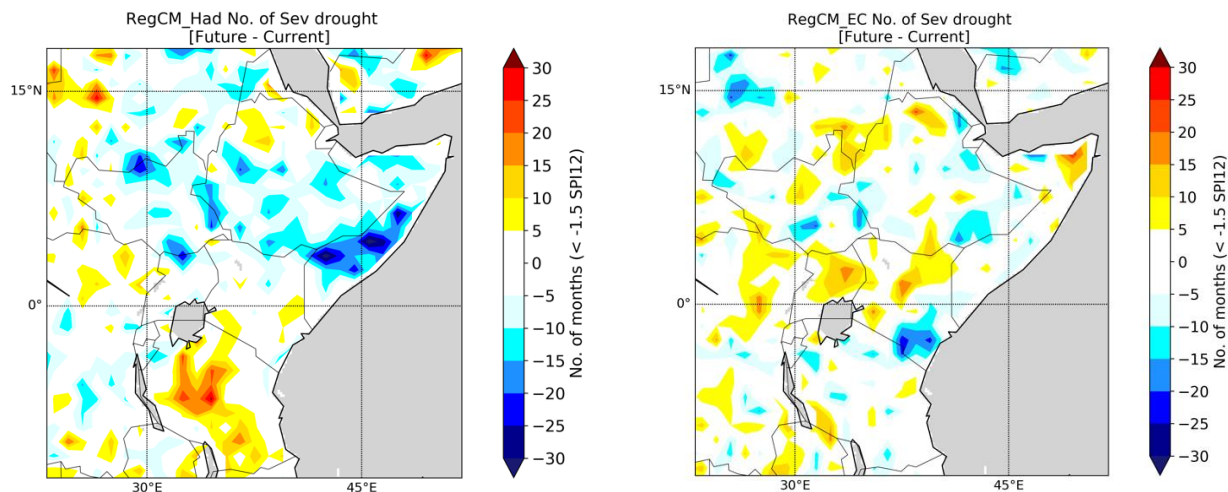


Figure 6. Change of SPI12 drought occurrence in the late 21st century (2077-2099) relative to current (1983-2005) from RegCM-HadGEM (left, Figure 6a) and RegCM4-ECEARTH (right, Figure 6b) simulations.

The results also show that the pattern of change is different in the two simulations (Figure 6a and Figure 6b) due to the difference in the driving data, even though the two simulations are derived from the same regional climate model. For instance, the projections from the HadGEM2-driven (Figure 6a) regional model show a decrease in the frequency of long-term drought over Somalia and southern Ethiopia and an increase in drought prevalence over central Tanzania. The EC-EARTH-driven simulation (Figure 6b), on the other hand, projected an increase in drought frequency over much of Tanzania and northern Ethiopia. The decrease in the frequency of severe to extreme droughts in HadGEM2-driven simulations, over Somalia and southern Ethiopia, is correlated with the increase in annual precipitation in many IPCC CMIP5 models. This relationship suggests that the decrease in drought occurrence is the result of fewer, but more intense, precipitation events rather than the outcome of a higher number of rainy days distributed across the year or growing season, which is more desirable for agriculture. Another interesting point about this region is that the current climate models project a decrease in drought frequency in the late 21st century, despite the upward trend of droughts in present day climate as shown in Viste et al. (2013) and Zeleke et al. (2017). Consequently, reconciling the present-day drying trend with the projected increase in intense precipitation is becoming an active area of research (Rowell et al. 2015).

To summarize, our analysis reveals that high-resolution models simulate the extreme events reasonably well, particularly the pattern of dry days over eastern African highlands. Two drought indicators, SPI12 and the frequency of dry days, are computed and compared for current and future climates. Projections based on the number of dry days indicated that 21st century droughts in the eastern parts of Africa will

tend to be longer and more frequent than those associated with the present climate. Another important result involves the prominent differences between the two indices for future drought projections, with the former indicating a drastic increase compared to the latter.

This study has focused on rainfall derived drought characteristics (e.g. SPI). Future work should also include the development of drought indices, such as Palmer Drought Severity Index (PDSI) and Standardized Precipitation-Evaporation Index (SPEI), that consider temperature and other atmospheric variables to determine robust drought statistics under climate change conditions. This analysis can be considered the first step towards quantifying and understanding eastern Africa's drought characteristics in current and future climates as determined from observations and high-resolution climate model simulations. It must be noted that there are several sources of uncertainties when projecting future droughts such as those related to model formulations and emission scenarios. Therefore, a comprehensive assessment of climate extremes, such as droughts, needs to be considered using multi-model simulations driven with multiple emission scenarios to capture the above range of uncertainties.

International migration in East Africa

Magnitude and trend

International migration in Africa has steadily increased over the past few decades. In 2017, 38 million Africans were living outside of their country of origin, the majority of whom (65 percent) were residing in another African country (IOM 2018). According to the UNDESA database, in 2017, emigrant stock from Africa are estimated to have accounted for around 15 percent of total international migrants in the world. Figure 7 shows migration trends in Africa (UNDESA 2017a). The number of emigrants found in Africa stagnated for a long period of time, increasing only in recent years.

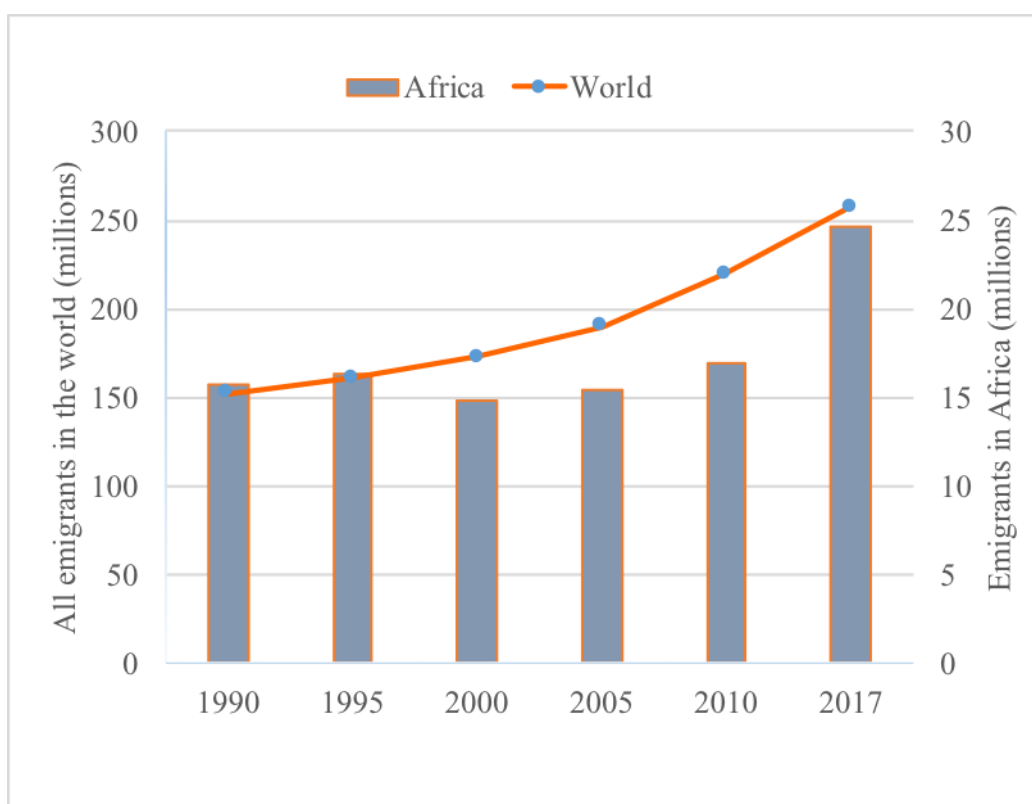


Figure 7: Trends of international emigrant stock found globally and in Africa. Source: Own computation based on UNDESA database, 2017a.

Like most of Africa, the eastern region has experienced significant, increasing international migration trends. Table 2 shows international migration from East African countries included in this study (i.e. Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan, Tanzania, and Uganda). Total international emigrant stock from the region almost doubled in the last two decades, from around 4.6 million in 1990 to 8.7 million in 2017. As seen in Figure 8, this is closely and positively correlated with the rapid growth

of the youth population in the region. It is essential to note, however, that the emigrant stock reported here captures only documented emigrants. Consequently, the total number of international emigrants who have left the region is likely to be even larger than what is reported here. In fact, various studies note (Shaw 2007, Marchand et al. 2017), many African migrants migrate through irregular or alternative routes and are often not recorded in official statistics.

Table 2. Trends of emigrant stock from sample countries from 1990 to 2017.

Country of origin	Total number of stock of emigrants by year						Annual growth rate
	1990	1995	2000	2005	2010	2017	
Eritrea	170,617	325,272	510,432	289,183	278,086	607,917	9.50%
Ethiopia	1,687,517	820,490	443,926	521,088	623,562	800,879	-2.00%
Kenya	242,119	267,084	308,199	344,121	407,446	501,204	4.00%
Somalia	846,967	899,478	1,004,443	1,150,483	1,578,233	1,988,458	5.00%
South Sudan	514,943	438,044	342,628	243,075	403,896	1,752,014	9.00%
Sudan	587,063	745,992	859,690	1,175,018	1,197,225	1,951,705	9.00%
Tanzania	204,272	232,062	220,108	238,881	267,834	324,394	2.00%
Uganda	311,490	469,323	552,835	557,486	702,606	739,667	5.00%
Total	4,564,988	4,197,745	4,242,261	4,519,335	5,458,888	8,666,238	3.00%

Source: UNDESA, 2017a.

A closer inspection of the data on emigrant stock originating from each sample country shows that the size of international migration from eastern Africa has varied over time and across countries in the sub-region. In terms of absolute size, Somalia, South Sudan and Sudan had, by far, the largest number of international emigrants in 2017, while in the 1990s, Ethiopia had the largest number of emigrants.

Table 3 reports the intensity of emigration for each of the case study countries. Intensity is given by the stock of emigrants as a share of total population in the source country. Tanzania consistently recorded the lowest emigration rates, with less than one percent (0.6-0.8 percent) of the population living abroad in the reporting period. Kenya has a slightly higher, constant emigration rate at one percent. Somalia has the highest emigration rate, with more than 10 percent of the population living outside of the country in all reporting periods. For other countries, the emigration rate fluctuates over time, often following incidences of political instability.

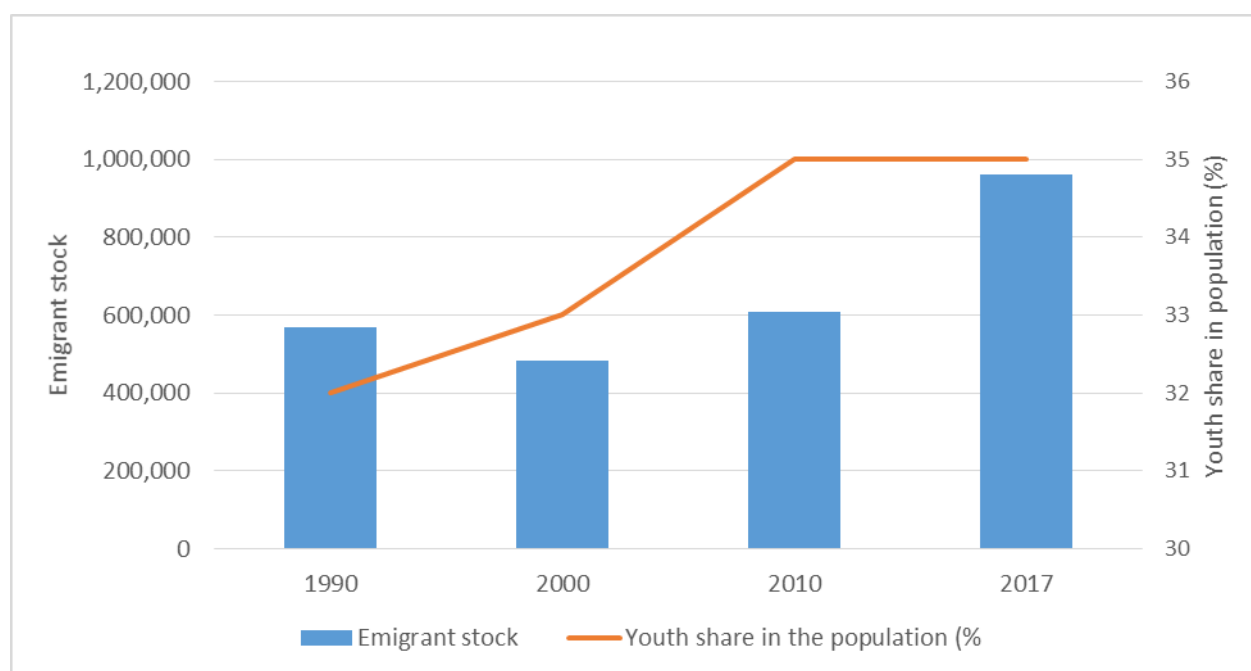


Figure 8: Trends of international emigrant stocks and emigrant intensity from and total youth population in study countries. Source: UNDESA (2017a, 2017b) and UN Population Statistics.

Table 3: Intensity of emigrant stock from the case study countries (per 100 people in origin country).

Country	Stock of migrants as a share of population size in the country of origin			
	1990	2000	2010	2017
Eritrea	5.5	15.0	6.3	12.0
Ethiopia	3.5	0.7	0.7	0.8
Kenya	1.0	1.0	1.0	1.0
Somalia	11.4	11.1	13.1	13.5
South Sudan	8.9	5.1	4.0	13.9
Sudan	2.9	3.2	3.5	4.8
Tanzania	0.8	0.6	0.6	0.6
Uganda	1.8	2.3	2.1	1.7
Total	3.0	2.1	2.0	2.6

Source: Own computation based on UNDESA (2017a, 2017c).

While most international migrants from the case study countries live within Africa, there is also significant migration to Europe, North America, the Middle East and other regions of the world. Table 4 presents the share of East African emigrants who live outside of Africa. In 1990, only two out of 10 international migrants from the case study countries emigrated to a non-African country. In the following

two decades, however, the share of emigrants from eastern Africa who lived outside Africa steadily increased, peaking in 2010 at about 44 percent. The most recent data from 2015 and 2017 show this share is declining (UNDESA 2017a).

Table 4. Destinations of emigrants from the sample countries: Percent share located outside Africa

Country of origin	Share of emigrants located outside of Africa						
	1990	1995	2000	2005	2010	2015	2017
Eritrea	20.1	15.6	13.0	30.5	46.2	30.4	30.7
Ethiopia	14.1	31.0	64.1	72.4	80.3	80.7	80.3
Kenya	67.2	70.3	70.2	73.3	74.2	74.3	71.5
Somalia	12.8	21.2	25.8	31.2	36.7	36.3	36.4
South Sudan	1.1	1.6	2.5	4.0	4.5	1.7	1.4
Sudan	49.8	43.8	43.1	39.4	54.0	40.1	42.1
Uganda	23.5	16.9	15.7	17.9	17.1	18.5	19.2
Tanzania	29.9	28.7	33.1	35.2	37.9	41.2	40.6
Total	21.4	27.7	32.2	38.3	43.9	35.6	35.0

Source: Own computation based on UNDESA (2017a).

The effect of climate change on East African migration

Projected effects on overall migration in the region: Literature

The eastern Africa region has recently suffered from repeated drought, floods and other disasters, resulting in significant displacement. In 2016, the region had the highest number of displacements in all of Africa, accounting for 63

“In 2016, East Africa had the highest number of displacements in all of Africa.”

percent of the continent’s displacement associated with sudden-onset disasters (IDMC 2017). With the changing climate, it is expected that the region will see more displacement and climate induced migrants in the coming years, with estimates placing the number of climate migrants in eastern Africa as high as 10.1 million by 2050 (Rigaud et al. 2018). Eastern Africa is expected to be both a hotspot for in-migration (receiving migrants) and out-migration (sending migrants), due to the effects of climate change. The most recent climate and population model projections suggest that the Lake Victoria Basin in the GHoA and the eastern highlands of Ethiopia are expected to be hotspots for in-migration, while coastal regions of Kenya and Tanzania, western Uganda and parts of the northern highlands of Ethiopia will become hotspots for out-migration (Rigaud et al., 2018). Note, however, that these figures are not for international migration.

Empirical analysis for the sample countries: Correlation between climate variables and international migration in East Africa

Below we discuss the empirical relationship between climate variables and international migration from East Africa. The analysis is based on migration data from UNDESA and climate data produced by our own climate modelling. Figure 8 shows the scatter plot and fitted, non-parametric regression between the drought indicator (annual dry days) and international emigration. The vertical axis shows the number of international emigrants from the study country, reported as a stock of emigrants in that year, and the horizontal axis shows the average number of annual dry days for the source country. We believe that the effect of drought in a particular year on the stock of emigrants is observed with a lag, and that insufficient rain in one year may not be enough to trigger migration. Hence the dry days in the horizontal axis show the average for the previous five years.

The plot shows that there is a positive correlation between the number of dry days the country experienced in the last five years and the number of international migrants from that country. The relationship is non-linear, with the effect of dry days increasing at higher levels.

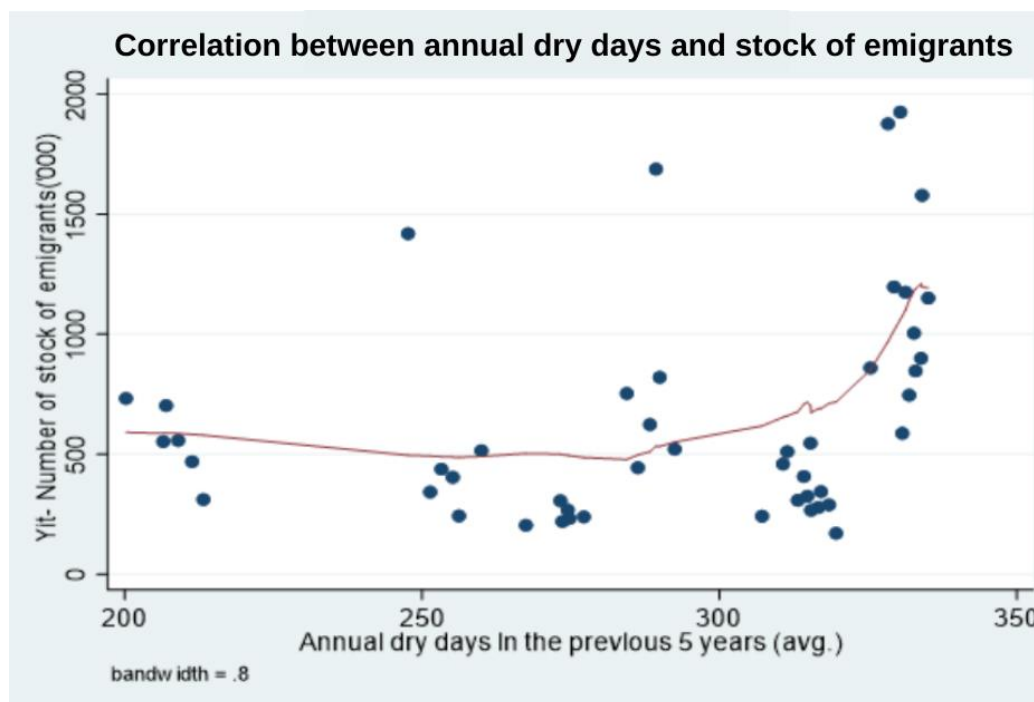


Figure 9: Correlation between annual dry days the country experiences in the previous five years and stock of emigrants from that country.

We also conducted a simple regression analysis where the number of dry days is regressed over the stock of emigrants. We controlled for trend by including a year variable. We also included agriculture's share of employment as an additional regressor, as the relative size of agriculture may have implications for emigration from these countries. Table 5 reports the results from the linear regression. Before discussing the results, we want to highlight that, given the data limitations discussed in Section 2,¹ we will only identify correlations and will not claim any causal relationship.

Table 5. Impact of drought on international migration (linear regression analysis for Eastern Africa).

	Stock of emigrants ('000)		
	Coefficient	Std. Err.	P-value
Annual number of dry days in the previous 5 years	3.385	1.539	0.033
Size of agriculture in the economy (as share of employment)	1.251	4.894	0.799
Year (trend)	15.722	7.232	0.035
Constant	-31896	14539	0.034
Number of observations			48
R-squared			0.17

Source: Own computation

In line with the non-parametric regression, we see that the number of dry days a country experienced in the past five years is positively correlated with the number of international emigrant stock from that country. More specifically, a one day increase in the number of annual dry days in a country is associated with approximately 3,400 more emigrant stock from that country. This relationship is significant at the 5 percent level. The size of agriculture in the economy is also positively correlated with the magnitude of emigrant stock, but it is not statistically significant. We see a strong, positive trend of emigration from the case study countries. More particularly, emigrant stock from these countries increases by almost 16,000 every five years.

Given the small sample size, we are reluctant to claim causality or emphasize the size of the effect. Despite the limitations, however, the overall results are in line with the results from previous empirical studies based on micro-level data. For example, earlier studies in Ethiopia and Tanzania show that migration is one of the most common responses for environmental-related shocks, such as drought (Gray and Mueller 2012, Kubik and Maurel 2016). The Tanzanian study shows that a one percent reduction in agricultural income, induced by short-term weather shocks, increases the probability of

¹ We have only eight countries for which emigration data is available from 1990 to 2015, at five years interval.

migration, on average, by 13 percent within the following year (Kubik and Maurel 2016). Similarly, a longitudinal study on population mobility and drought in Ethiopia shows that men's labor migration increases with drought and that land-poor households are the most vulnerable (Gray and Mueller 2012), demonstrating the linkage between climate extremes, agricultural livelihoods and migration.

New pressures on old challenges: Climate change effects on youth migration

In 2017, about 31 percent of international migrants were young people between the ages of 15 and 34 (UNDESA 2017a). Female youth accounted for nearly 47 percent of the

“Eastern Africa has been deemed a climate “hotspot.””

total youth international migrants in the same year. This figure is based on age-disaggregated data available from receiving countries. Unfortunately, published quantitative data on youth international migration from Africa, as well as from other developing regions, is not available to directly examine the magnitude and trends of youth migration from the case study countries.

Africa has the youngest population in the world, with 60 percent below 25 years of age (UNDESA 2017c). Currently, there is a large youth population joining the labor market in both urban and rural areas, often with more education than previous generations. African economies, including those in eastern African countries, need to rapidly create a large number of jobs to meet the livelihood needs of the new labor force. However, as these are predominantly agricultural economies, it is increasingly difficult to create jobs that are suitable and attractive enough for the youth, resulting in large rural-urban migration (Bezu and Holden 2014, Fox et al. 2016). This is likely to get worse and generate more international migration unless the sector is significantly transformed with a higher number of jobs that are innovative and which attract young people. These structural economic problems are exacerbated by the pressure from climate change as the environmental and agroecological changes result in lower crop productivity, more land scarcity and higher risks of extreme weather events (Rigaud et al. 2018). Data from case study countries in SSA show that 60 percent of internal migrants are between the age of 15 and 34 years old (Mercandalli and Losch 2017).

Within Africa, eastern Africa has been deemed a climate “hotspot,” or a place where a changing climate could pose grave threats to food security and human well-being (Woolf et al. 2018). The East African region is perhaps even more likely than the rest of the continent to experience a rapid increase in youth international migration. The share of the youth population in eastern Africa at 35 percent, is the highest in Africa (UNDESA 2017d). Since subsistence agriculture is the main source of livelihoods in this region, the youth are mostly engaged in agricultural activities. The region experienced repeated and significant weather- and climate-related shocks in recent years and is vulnerable to further climate change impacts. All of this suggests the possibility of significant, climate-induced migration in the coming years.

Adapting agriculture to climate change in eastern Africa

Estimates by the World Bank (2010) indicate that developing countries bear around 70-80 percent of costs related to climate change damages. This is due to their heavy reliance on ecosystem services and natural capital for agricultural production, high exposure to climate variability and change, poverty and limited financial and institutional capacity to adapt to climate change (WB 2010). Increasing adaptation to climate change is crucial to minimize current and future negative impacts (WB 2010).

Developing countries will bear the brunt of climate damages. Climate-smart agriculture, weather-index insurance, social safety-net programs and planned relocation can help agricultural systems and communities adapt to a changing climate.

According to the IPCC (2007), adaptation is an “adjustment to human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.” A growing body of empirical literature, however, documents that the decision to adapt to climate change depends on interacting environmental, social, political and economic factors, operating at multiple scales (Deryng et al. 2011, Rigaud et al. 2018, Clay and King 2019). Available literature also shows that populations living in developing countries generally use a wide range of strategies to adapt to climate variability, climate change and weather extremes (Zilberman et al. 2012). According to the Food and Agriculture Organization of the United Nations (FAO), climate change is considered a significant threat-multiplier to factors that cause youth migration, especially in agriculture-dependent populations and regions, such as eastern Africa (FAO 2017). Climate-smart agriculture (CSA) and climate-smart adaptation strategies are useful mechanisms to reduce youth out-migration by creating local economic opportunities, encouraging youth to stay rather than abandon their agricultural lands.

Climate-smart agriculture

Since its launch by the FAO in 2009, CSA has increased in popularity at the international and national levels. CSA is an approach to transform agricultural systems and to support food security under a changing climate by providing context-specific and flexible solutions (Lipper et al. 2014). CSA practices can be heterogeneous over time and across locations and may encompass technological, institutional and policy solutions (Mirzabaev 2018). As described by the FAO (2013), a number of agricultural technologies and practices fall under CSA, including stress-adapted crop varieties and livestock breeds, improved seeds, crop diversification, conservation agriculture (e.g. reduced- or zero-tillage), water

management (e.g. irrigation and water storage), agroforestry and integrated soil management practices (e.g. mulching and crop rotation). Previous studies in SSA demonstrate that the adoption of CSA technologies and practices has generated multiple benefits, including improved agricultural yields, food security and increased income in the context of climate change and variability (Makate 2019). Despite this, the adoption of effective CSA technologies and practices by smallholder farmers in Africa remains limited. Appropriate financial, policy and institutional arrangements are needed to scale-up existing CSA technologies and practices and to enable smallholder African farmers to benefit from them at scale (Makate 2019). In fact, the African Development Bank (AfDB) is committed to adapting to climate change through climate-smart financing of development, including agriculture (AFDB 2018), which could possibly minimize the forced out-migration of rural labor (FAO 2017).

Weather-index insurance

In addition to damaging the current asset-base of the population and inducing the displacement of both adults and youth, climate extremes will also reduce the confidence of people to invest in productive endeavors. In this regard, institutional innovations, such as weather-index insurance (WII), have received increased attention in the context of climate change adaptation (WB 2010). Previous empirical studies indicate that WII reduced weather-related, distress livestock sales in Kenya (Janzen and Carter 2013) and increased the adoption of improved farm technologies and practices in Ethiopia (Madajewicz et al. 2013), possibly reducing the need for out-migration as a risk management strategy.

Social safety-net programs

Social protection measures can be useful instruments to cope with weather shocks caused by climate change. Productive safety-net programs (PSNP), implemented by the Government of Ethiopia since 2005, are useful example for the case in point. By implementing climate-smart initiatives (CSI) within PSNP (WB 2013, Solomon et al. 2016, Woolf et al. 2018) Ethiopia has been able to significantly cope with drought shocks while also building community-based infrastructure and natural capital (Berhane et al. 2014). A study by Deshingkar et al. (2013), based on household-level data from Ethiopia, Kenya, Tanzania and Malawi, shows that social protections tend to reduce the need for out-migration. However, the authors argue that this may not always be desirable as it could increase mal-adaptation, trapping people in unsustainable livelihood strategies in the context of deteriorating conditions. They recommend that apart from smoothing consumption, social protection policies should be designed to enable rural households to diversify their income sources, including through migrating. On the contrary, Woolf et al. (2018) used biophysical data, collected from Ethiopian regional states, with results indicating that

climate-smart PSNP can contribute to climate change mitigation by creating a vehicle for investment in land and ecosystem restoration. The authors highlighted that maximizing mitigation, while enhancing but not compromising the rehabilitation of degraded ecosystems and food security, requires effective climate scenario and vulnerability analysis and projections. Additionally, mitigation and adaptation responses should be mainstreamed into the overall planning and implementation of climate-smart PSNP at all levels and scales.

Migration as a household adaptation strategy

Migration can be an effective adaptation strategy in a changing climate (Warner et al. 2009, WB 2010, Zilberman et al. 2012, Baldwin 2013, IPCC 2014c, Millock 2015). In cases where climate migrants choose when and where to migrate, instead of being suddenly forced to migrate, migration often benefits the migrant, their family and the host community (Harttgen and Klasen 2011, Melde et al. 2017, UNDP 2009). Evidence also suggests that remittances from migrants improve the adaptive capacity and recovery of households exposed to environmental shocks (Mohapatra et al. 2009, Nganga et al. 2016, Banerjee et al. 2017).

Meze-Hausken (2000) found that climate-induced migration from rural areas in northern Ethiopia has increased in the wake of severe droughts. Using data from Ethiopian rural household surveys, Gray and Mueller (2012) also find that self-reported drought increases the likelihood of domestic migration. In northern Kenya, Nganga et al. (2016) used data from agro-pastoral households to show that the out-migration of a household member increases the adoption of climate change adaptation practices (e.g. purchasing of drought-tolerant livestock and other self-protection measures) by migrant-sending households. According to the authors, the main underlying mechanism linking migration to the adoption of adaptation practices is remittances received from the migrants, which reduced capital constraints to finance the uptake of adaptation measures. Not all households, however, are able to utilize migration as an adaptive strategy since migration, especially to distant places, is often an arduous, risky and expensive process. Moreover, there is evidence to suggest that adverse environmental conditions also reduce long-distance mobility by depriving people of the necessary resources to finance the move (UNECA 2017). A recent study in Tanzania shows that migration is an important response to manage the loss of agricultural income caused by climate variability and weather shocks among households in the middle-wealth category (Kubik and Maurel, 2016). The main reason for this is that the poorest households cannot afford migration costs while households that are more well-off financially can apply other adaptation strategies, like irrigation or drought-resistant crops (Kubik and Maurel 2016).

Planned relocation or resettlement

In cases where the damage from climate variability and change on the natural environment and associated ecosystem services is such that the landscape is unable to support the existing population, it is important to plan for relocation and resettlement. Ignoring and delaying policy responses in such cases may result in unmanageable, large-scale migration, resulting in humanitarian, logistical and political crisis (Foresight 2011). Moreover, the most vulnerable group may be trapped in uninhabitable places, becoming even more impoverished and threatened with irrevocable damage to their health. Planned relocation or resettlement of people from areas vulnerable to climate or weather extremes is, thus, an important climate adaptation strategy (Raleigh et al. 2008, Foresight 2011, Rigaud et al. 2018). Migration in this climate-induced system can be voluntary or incentivized to motivate people to move from areas exposed to climate hazards to safe environments within or outside a given country. Typically, such measures are planned and executed by governments, perhaps in conjunction with civil societies and human rights groups. However, it is important to note here that government induced resettlement in developing countries has not been popular in the past and experienced various degrees of failure (Black et al. 2008). For example, following severe droughts in Ethiopia between 1984-85, the government resettled about 600,000 people from drought-affected central and northern Ethiopia to southwest Ethiopia, where the land is more fertile and favorable for sustainable agriculture (Rahmato 1989). This program was highly contested and faced several challenges at the time (Ezra and Kiros 2001, Black et al. 2008). In 2003, a new voluntary resettlement program was again initiated by the government as part of its national food security strategy. Although hailed by the Ethiopian government and some scholars as a success (Kassa 2004, Lemenih et al. 2014), the renewed resettlement program has been criticized for inadequate planning and resourcing, marginalizing the poorest of the poor and blocking access of non-governmental organizations, civil society and other independent observers from the resettlement schemes (Hammond and Dessalegn 2004, Hammond 2008). It is imperative to learn from past mistakes to design a forward-thinking resettlement plan. A reactive relocation in an emergency is a sign of adaptation failure (Frankhauser 2017).

Summary of findings

This study assessed the link between climate change, agriculture and international migration. We provided a conceptual framework that shows the link between climate change and migration through its effect on agricultural livelihoods. The study focuses on eight eastern African countries, including Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan, Tanzania and Uganda, and explores the climate change-agriculture-international migration nexus from the youth perspective. Below we highlight the main findings of this study:

1. Existing empirical evidence suggests that climate change is associated with increased migration

Climate change is expected to trigger unprecedented levels of migration in the coming decades, including from eastern Africa. Existing empirical literature shows that:

- Temperature and precipitation are closely correlated with migration flow.
- The impact of climate change on international migration is stronger for agricultural countries and communities.
- Migration incident is higher among the youth population.
- Although women in developing countries are expected to experience more pressure to migrate, they are not necessarily more likely to migrate due to fewer resources, cultural constraints regarding their mobility, and stronger responsibilities towards less mobile members of the household.

2. Climate change trends and projections in East Africa

- The East Africa region has recently suffered from repeated drought, floods and other disasters that result in significant out-migration.
- Results from our climate model show that the East African region will experience longer and more frequent droughts than those associated with the present climate.
- Agricultural livelihoods in East Africa will be more vulnerable in the coming decades, potentially leading to additional, significant local and international outmigration.

3. Migration trends in East Africa

- In 2016, the eastern Africa region had recorded the highest number of out-migration in all of Africa.

- 63 percent of the continent's displacement associated with or triggered by sudden-onset disasters is accounted for by East African countries.
- Migration from eastern Africa almost doubled in the past two decades, with the stock of international emigrants from the region increasing from 4.6 million in 1990 to 8.7 million in 2017. This figure does not include irregular migrants.
- Most eastern African migrants live within Africa; however, recent trends show an increase in the share of emigrants living outside of Africa including the Middle East, Europe, Australia and North America.
- There is significant difference among eastern African countries in terms of intensity of emigration. Less than one percent of Tanzanians live outside of their country while for Somalia, that share is at 10 percent. For the region, the rate is two to three percent in the period 1990 to 2017.

4. The impact of climate change on international migration in eastern Africa

- Quantitative analysis shows that international migration in eastern Africa is correlated with drought.
- A higher number of average dry days for a country is positively correlated with a higher stock of emigrants from that country.
- An increase in the number of annual dry days is associated with increased emigration. For every one day increase of annual dry days in a country, 3,400 emigrants can be expected from that country.
- Given the significance of agriculture as a livelihood source, the positive correlation between climate change indicator dry days and emigration is not unexpected, in line with other findings in the literature. However, given the limited sample size in our data, this result needs to be interpreted with caution.

5. The prospect of youth international migration from East Africa is high and increasing with climate change

- Africa has the youngest population in the world, with 65 percent of the population below 25 years.
- The share of the youth population in eastern Africa is 35 percent, making it the highest in Africa.
- The eastern African region is poised to experience significant youth migration in the coming decades due to direct and indirect impacts of climate change on livelihoods.

- The youth in eastern Africa are more likely to be unemployed, less encumbered with family responsibilities and have more education than previous generations. All of these increase the likelihood of youth migration in the context of climate change.
- Age-disaggregated statistics on emigration from East Africa are not readily available and there are few studies on international migration from Africa. Existing, indirect evidence, however, suggests there is higher migration among the youth in Africa.
- For example, statistics from case study countries show that 60 percent of internal migrants are between the ages of 15 and 34.

6. There are various potential adaptation measures, but success depends on careful planning and policy coordination

- *CSA*: Existing evidence from several SSA countries suggests that the adoption of CSA improves agricultural yields, food security, livelihoods and income in the context of climate change and variability. However, adoption of effective CSA technologies and practices by smallholder farmers in Africa remains limited.
- *Weather Index Insurance*: Empirical evidence from Ethiopia and Kenya indicates that this adoption strategy is promising in terms of protecting assets and facilitating improved technology adoption, possibly reducing the forced out-migration of labor. The main concern with this strategy is that it is difficult to insure all affected when climate change affects a large group of people simultaneously.
- *Safety-net programs*: Safety-net programs can be useful instruments to cope with weather shocks caused by climate change, such as droughts. There is some evidence from East Africa suggesting that such programs reduce out-migration. However, there have been concerns over the crowding effect of such programs on private and informal insurance.
- *Relocation and resettlement*: Planned relocation or resettlement, from areas vulnerable to climate change, is an important climate adaptation strategy. However, due to the size and logistics needs, resettlement and relocation demand strong government involvement. Unfortunately, past government-led relocations in Africa have not been successful and any new relocation strategy needs careful assessment.
- *Migration as adaptation strategy*: There is ample evidence in the literature, across different countries, showing that agricultural households' resort to migration as a response to environmental shocks and as an income diversification strategy in the face of risk. Not all

individuals, however, are able to migrate as an adaptation strategy, but may be displaced without preparation after they exhaust their resources and capacity. Proactive migration as an adaptation strategy can increase the climate resilience of vulnerable rural populations dependent on agriculture.

Further research

Our extensive review of research on climate change and migration identified key research gaps that need to be filled to craft informed policy and programs, including:

Rigorous research on youth livelihoods and migration in Africa. Although there are many references to youth migration and suggestive evidence on the increased level of youth migration in Africa, we found limited research on patterns, drivers and impacts of youth migration. With climate change, we need more information about how people respond to environmental changes and how the responses change over time. We suggest exploring the possibility of conducting cross-country studies for East Africa using the World Bank's Living Standards Measurement Study (LSMS) survey, which has been implemented in several African countries. Such analysis could be supplemented with a more in-depth study based on survey data from one of the countries.

More work to quantify East Africa's drought characteristics in current and future climates. In this study, we provided a simple quantification of drought in East Africa using a regional model. It is noted that there are several sources of uncertainties when projecting future droughts, such as those related to model formulations and emission scenarios. Therefore, a comprehensive assessment of climate extremes, such as droughts, needs to be considered using multi-model simulations driven with multiple emission scenarios to capture the above ranges of uncertainties. Future work should also include the development of drought indices, such as PDSI and SPEI, that consider temperature and other atmospheric variables to determine robust drought statistics under climate change conditions.

References

- Afifi T, Warner K. 2008. The impact of environmental degradation on migration flows across countries
Working paper: UNU-EHS.
- African Development Bank (AfDB). 2016. Growth, Poverty and Inequality Nexus: Overcoming Barriers to Sustainable Development. African Development Report 2015.
- AFDB. 2018. Inclusive Climate-Smart Finance. African Development Bank Group.
- African Union (AU). undated. The Revised Policy Framework for Africa and Plan of Action [2018-2027]:
- Antman FM. 2013. 16 The impact of migration on family left behind. International handbook on the economics of migration (p 293).
- Arora-Jonsson S. 2011. Virtue and vulnerability: Discourses on women, gender and climate change. *Global Environmental Change*, 21(2), 744-751. doi: <https://doi.org/10.1016/j.gloenvcha.2011.01.005>
- AU. 2006. African Youth Charter. Adopted by the seventh ordinary session of the assembly on July 2, 2006, in Banjul, The Gambia. [Available online: <http://www.au.int/en/content/african-youth-charter>]
- Backhaus A, Martinez-Zarzoso I, Muris C. 2015. Do climate variations explain bilateral migration? A gravity model analysis. *IZA Journal of Migration*, 4, 3-X.
- Baldwin A. 2013. Racialization and the figure of the climate-change migrant. *Environment and Planning A*, 45, 1474-1490.
- Banerjee S, Kniveton D, Black R, Bisht S, Das PJ, Mahapatra B, Tuladhar S. 2017. Do Financial Remittances Build Household-Level Adaptive Capacity? A Case Study of Flood-Affected Households in India.
- Barnett J, Webber M. 2010. Accommodating migration to promote adaptation to climate change. Background Paper to the 2010 World Development Report. World Bank Policy Research Working Paper 5270.
- Beine M, Parsons C. 2015. Climatic factors as determinants of international migration. *Scandinavians Journal of Economics*, 117, 723–67.
- Berhane G, Gilligan D, Hoddinott J, Kumar N, Taffesse A. 2014. Can social protection work in Africa? The impact of Ethiopia's productive safety net programme. *Economic Development and Cultural Change* 63, 1-26.
- Bettini G. 2017. Where Next? Climate Change, Migration, and the (Bio)politics of Adaptation. *Global Policy*, 8(S1), 33-39. doi: <https://doi.org/10.1111/1758-5899.12404>
- Bezu S, Holden S. 2014. Are Rural Youth in Ethiopia Abandoning Agriculture? *World Development*, 64, 259-272.
- Black R, Knive D, Skeldon R, Coppard D, Murate A, Schmidt-Verkerk K. 2008. Demographics and climate change: future trends and their policy implications for migration. Working Paper T-27, Development Research Center on Migration, Globalization and Poverty, University of Sussex, UK.
- Black R, Kniveton D, Schmidt-Verkerk K. 2011. Migration and Climate Change: Towards an Integrated Assessment of Sensitivity. *Environment and Planning A: Economy and Space*, 43(2), 431-450. doi: 10.1068/a43154

- Bohra-Mishra P, Oppenheimer M, Hsiang SM. 2014. Nonlinear permanent migration response to climatic variations but minimal response to disasters. *Proceedings of the national academy of sciences*, 111(27), 9780. doi: 10.1073/pnas.1317166111
- Bryan E, Ringler C, Okoba B, Roncoli C, Silvestri S, Herrero M. 2013. Adapting agriculture to climate change in Kenya: household strategies and determinants. *Journal of Environmental Management*, 114, 26-35.
- Cai R, Feng S, Oppenheimer M, Pytlikova M. 2016. Climate variability and international migration: The importance of the agricultural linkage. *Journal of Environmental Economics and Management*, 79, 135-151. doi: <https://doi.org/10.1016/j.jeem.2016.06.005>
- Cannon T. 2002. Gender and climate hazards in Bangladesh. *Gender & Development*, 10(2), 45-50.
- Castles S. 2002. Environmental change and forced migration: making sense of the debate: UNHCR.
- Castles S, De Haas H, Miller MJ. 2013. The age of migration: International population movements in the modern world: Macmillan International Higher Education.
- Chindarkar N. 2012. Gender and climate change-induced migration: proposing a framework for analysis. *Environmental Research Letters*, 7(2), 025601.
- Clay N, King B. 2019. Smallholders' uneven capacities to adapt to climate change amid Africa's 'green revolution': Case study of Rwanda's crop intensification program. *World Development*, 116, 1-14
- De Haan A. 1999. Livelihoods and poverty: The role of migration-a critical review of the migration literature. *The Journal of Development Studies*, 36(2), 1-47.
- Dell M, Jones BF, Olken BA. 2012. Temperature Shocks and Economic Growth: Evidence from the Last Half Century. *American Economic Journal: Macroeconomics*, 4(3), 66-95. doi: 10.1257/mac.4.3.66
- Deshingkar P, Wood RG, Bene C. 2013. Adaptive Social Protection and Migration: The Case of Cash Transfers in Ethiopia, Kenya, Malawi and Tanzania. Migrating Out of Poverty Research Program Consortium. Final Report.
- Duru MJ. 2016. Too certain to invest? Public safety nets and insurance markets in Ethiopia. *World Development*, 78, 37-51.
- Eastin J. 2018. Climate change and gender equality in developing states. *World development*, 107, 289-305. doi: <https://doi.org/10.1016/j.worlddev.2018.02.021>
- Ezra M, Kiros G. 2001. Rural Outmigration in the Drought-prone Areas of Ethiopia: A Multi-level Analysis. *International Migration Review*, 35, 749-771.
- FAO. 2013. Climate-Smart Agriculture: Sourcebook. Rome: FAO. Available at: <http://www.fao.org>
- FAO. 2017. Migration, Agriculture and Climate Change: Reducing Vulnerabilities and Enhancing Resilience. Available at: <http://www.fao.org/3/i8297EN/i8297en.pdf>
- Feng S, Krueger AB, Oppenheimer M. 2010. Linkages among climate change, crop yields and Mexico-US cross-border migration. *Proceedings of the national academy of sciences*, 107(32), 14257-14262.
- Flahaux M, De Haas H. 2016. African migration: trends, patterns, and drivers. *Comparative Migration Studies*, 4(1), 1-25.
- Foresight. 2011. Migration and global environmental change *Final Project Report*. London: The Government Office for Science.
- Frankhauser S. 2017. Adaptation to climate change. *Annual Review of Resource Economics*, 9, 209-230.

- Fox L, Senbet LW, Simbanegavi W. 2016. Youth Employment in Sub-Saharan Africa: Challenges, Constraints and Opportunities. *Journal of African Economies*, 25(suppl_1), i3-i15. doi: 10.1093/jae/ejv027
- Gemenne F. 2011. How they became the human face of climate change. Research and policy interactions in the birth of the 'environmental migration' concept. *Migration and climate change*.
- GHF. 2009. Human Impact Report: Climate Change - The Anatomy of a Silent Crisis. Geneva: Global Humanitarian Forum.
- Gray C, Mueller V. 2012. Drought and Population Mobility in Rural Ethiopia. *World development*, 40(1), 134-145. doi: <https://doi.org/10.1016/j.worlddev.2011.05.023>
- Hammond L. 2008. Strategies of Invisibilization: How Ethiopia's resettlement program hides the poorest of the poor. *Journal of Refugee Studies*, 21(4), 517-536.
- Hammond L, Dessalegn B. 2004. Evaluation of the 2003 Pilot Resettlement Safara' Programme. In People, Space and the State: Migration, Resettlement and Displacement in Ethiopia, Pankhurst A, Piguet F (eds.), Society of Sociologists, Social Workers and Anthropologists, Addis Ababa University: Addis Ababa, Ethiopia.
- Hansen J, Hellin J, Rosenstock T, Fisher E, Cairns J, Stirling C, Lamanna C, van Etten J, Rose A, Campbell B. 2019. Climate risk management and rural poverty reduction. *Agricultural Systems*
- Harttgen K, Klasen S. 2011. A Human Development Index by Internal Migrational Status. *Journal of Human Development and Capabilities*, 12(3), 393-424. doi: 10.1080/19452829.2011.576819
<https://www.nature.com/articles/nclimate2103#supplementary-information>
- IDMC. 2017. Africa Report on Internal Displacement: Internal Displacement Monitoring Center.
- IOM. 2018. *GLOBAL MIGRATION INDICATORS*: Global Migration Data Analysis Centre (GMDAC). International Organization for Migration.
- Ionesco D, Mokhnacheva D, Gemenne F. 2016. *The atlas of environmental migration*: Routledge.
- IPCC. 2014a. Climate Change 2014 – Impacts, Adaptation and Vulnerability. Part A: Emergent Risks and Key Vulnerabilities. Working Group II Contribution to the IPCC Fifth Assessment Report. Cambridge: Cambridge University Press.
- IPCC. 2014b. Climate Change 2014 – Impacts, Adaptation and Vulnerability. Part A: Human Security. Working Group II Contribution to the IPCC Fifth Assessment Report. Cambridge: Cambridge University Press. Cambridge, UK: Cambridge University Press.
- IPCC. 2014c. 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.
- IPCC. 2018. Global warming of 1.5°C : An IPCC Special Report. Geneva, Switzerland: International Panel for Climate Change.
- Jakobeit C, Methmann C. 2012. 'Climate Refugees' as Dawning Catastrophe? A Critique of the Dominant Quest for Numbers. In J. Scheffran, M. Brzoska, H. G. Brauch, P. M. Link & J. Schilling (Eds.), *Climate Change, Human Security and Violent Conflict: Challenges for Societal Stability* (pp. 301-314). Berlin, Heidelberg: Springer Berlin Heidelberg.
- Janzen SA, Carter MR. 2013. The impact of micro-insurance on consumption smoothing and asset protection: evidence from a drought in Kenya. In: University of California at Davis. Presented at

- Agricultural and Applied Economics Association's 2013 AAEA and CAES Joint Annual Meeting, Washington, DC.
- Joseph G, Wodon Q. 2013. Is internal migration in Yemen driven by climate or socio-economic factors? *Review of International Economics*, 21(2), 295-310.
- Joseph M, Tuccio, M. 2016. Climate instability, urbanization and international migration. *Journal of Development Studies*, 55(5), 735-752.
- Kassa B. 2004. Resettlement of Peasants in Ethiopia. *Journal of Rural Development*, 27, 223–253.
- Kubik Z, Maurel M. 2016. Weather Shocks, Agricultural Production and Migration: Evidence from Tanzania. *The Journal of Development Studies*, 52(5), 665-680. doi: 10.1080/00220388.2015.1107049
- Kurnik B, Barbosa P, Vogt J. 2011. Testing two different precipitation datasets to compute the standardized precipitation index over the Horn of Africa. *International Journal of Remote Sensing*, 32(21), 5947-5964.
- Lemenih M, Kassa H, Kassie GT, Abebaw D, Teka W. 2014. Resettlement and Woodland Management Problems and Options: A Case Study from North-Western Ethiopia. *Land Degradation and Development*, 25, 305-318.
- Lipper L, Thornton P, Campbell BM, Baedeker T, Braimoh A, Bwalya M, Caron P, Cattaneo A, Garrity D, Henry K, Hottle R, Jackson L, Jarvis A, Kossam F, Mann W, McCarthy N, Meybeck A, Neufeldt H, Remington T, Sen PT, Sessa R, Shula R, Tibu A, Torquebiau EF. 2014. Climate-smart Agriculture for Food Security. *Nature Climate Change*, 4, 1068-1072.
- Lipton M. 1980. Migration from rural areas of poor countries: the impact on rural productivity and income distribution. *World development*, 8(1), 1-24.
- Madajewicz M, Tsegay AH, Norton M. 2013. Managing Risks to Agricultural Livelihoods: Impact Evaluation of the HARITA Program in Tigray, Ethiopia, 2009–2012. Oxfam America, Boston.
- Makate C. 2019. Effective Scaling of Climate Smart Agriculture Innovations in African Smallholder Agriculture: A Review of Approaches, Policy and Institutional Strategy Needs. *Environmental Science and Policy*, 96, 37-51.
- Marchand K, Reinold J, Silvia RD. 2017. Study on migration routes in the East and Horn of Africa. Maastricht Graduate School of Governance (MGSoG).
- Marchiori L, Maystadt JF, Schumacher I. 2012. The impact of weather anomalies on migration in sub-Saharan Africa. *Journal of Environmental Economics and Management*, 63(3), 355-374. doi: <https://doi.org/10.1016/j.jeem.2012.02.001>
- Massey DS, Axinn WG, Ghimire DJ. 2010. Environmental change and out-migration: evidence from Nepal. *Population and environment*, 32(2), 109-136. doi: 10.1007/s11111-010-0119-8
- Mastrorillo M, Licker R, Bohra-Mishra P, Fagiolo G, Estes LD, Oppenheimer M. 2016. The influence of climate variability on internal migration flows in South Africa. *Global Environmental Change*, 39, 155-169. doi: <https://doi.org/10.1016/j.gloenvcha.2016.04.014>
- Maurel M, Tuccio M. 2016. Climate Instability, Urbanisation and International Migration. *The Journal of Development Studies*, 52(5), 735-752. doi: 10.1080/00220388.2015.1121240
- Maystadt JF, Mueller V. 2012. Environmental migrants: a myth? International Food Policy Research Institute (IFPRI).

- Melde S, Laczko F, Gemenne F. 2017. Making Mobility Work For Adaptation to Environmental Changes. Geneva: IOM.
- Mercandalli S, Losch B. 2017. *Rural Africa in motion. Dynamics and drivers of migration South of the Sahara*: FAO.
- Meze-Hausken E. 2000. Migration caused by climate Change: How Vulnerable are people in dryland areas? a case study in northern Ethiopia. *Mitigation and Adaptation Strategies for Global Change*, 5(4), 379–406.
- Millock K. 2015. Migration and environment. *Annual Review of Resource Economics*, 7, 35-60.
- Mirzabaev A. 2018. Improving the resilience of central Asian agriculture to weather variability and climate change: Climate Smart Agriculture: Building Resilience to Climate Change. In Lipper L, McCarthy N, Zilberman D, Asfaw S, Branca G. (Editors).
- Mohapatra S, Joseph G, Ratha D. 2009. *Remittances and natural disasters: ex-post response and contribution to ex-ante preparedness*: The World Bank.
- Mueller V, Quisumbing A. 2010. Short and long-term effects of the 1998 Bangladesh flood on rural wages: Citeseer.
- Mueller V, Gray C, Kosec K. 2014. Heat stress increases long-term human migration in rural Pakistan. *Nature Climate Change*, 4, 182. doi: 10.1038/nclimate2103
- Myers N, Kent J. 1995. *Environmental exodus: an emergent crisis in the global arena*: Climate Institute.
- Naudé W. 2009. Natural disasters and international migration from Sub-Saharan Africa. *Migration Letters*, 6(2), 165.
- Nawrotzki RJ, Riosmena F, Hunter LM. 2013. Do rainfall deficits predict US-bound migration from rural Mexico? Evidence from the Mexican census. *Population research and policy review*, 32(1), 129-158.
- Nganga SK, Bulte EH, Giller KE, McIntire JM, Rufino FE. 2016. Migration and self-protection against climate change: a case study of Samburu county, Kenya. *World Development*, 84, 55-68.
- Nicholson CT. 2014. Climate change and the politics of causal reasoning: the case of climate change and migration. *The Geographical Journal*, 180(2), 151-160.
- Perch-Nielsen SL, Bättig MB, Imboden D. 2008. Exploring the link between climate change and migration. *Climatic change*, 91(3-4), 375.
- Piguet E, Laczko F. 2013. People on the move in a changing climate: The regional impact of environmental change on migration (Vol. 2): Springer Science & Business Media.
- Rahmato D. 1989. *Famine and survival strategies: A case study from northeast, food and famine*. Institute of Development Research, Monograph, No. 1. Addis Ababa University, Ethiopia.
- Raleigh C, Jordan L, Salehyan I. Undated. Assessing the Impact of Climate Change on Migration and Conflict. <http://siteresources.worldbank.org/extsocialdevelopment>.
- Raleigh C, Jordan L, Salehyan I. 2008. Assessing the impact of climate change on migration and conflict. Paper presented at the Paper commissioned by the World Bank Group for the Social Dimensions of Climate Change workshop, Washington, DC.
- Ray DK, West PC, Clark M, Gerber JS, Prishchepov V, Chatterjee S. 2019. Climate change has likely already affected global food production. *PLoS ONE* 14(5): e0217148. <https://doi.org/10.1371/journal.pone.0217148>

- Renaud FG, Dun O, Warner K, Bogardi J. 2011. A decision framework for environmentally induced migration. *International Migration*, 49, 5-29.
- Rigaud KK, de Sherbinin A, Jones B, Bergmann J, Clement V, Ober K, Schewe J, Adamo S, McCusker B, Heuser S, Midgley A. 2018. Groundswell: Preparing for Internal Climate Migration. Washington, DC: The World Bank.
- Seema J. 2006. Selling Labor Low: Wage Responses to Productivity Shocks in Developing Countries. *Journal of political economy*, 114(3), 538-575. doi: 10.1086/503579
- Shaw W. 2007. Migration in Africa: A Review of the Economic Literature on International Migration in 10 Countries. Development Prospects Group, The World Bank.
- Solomon D, Woolf D, Jirka S, De’Gloria S, Belay B, Ambaw G, Getahun K, Ahmed M, Ahmed Z, Lehmann L. 2016. Ethiopia’s Productive Safety Net Program (PSNP): Soil carbon and fertility impact assessment. A World Bank Climate Smart Initiative (CSI) Report. Cornell University.
- Stern NH. 2007. The Stern Review of the Economics of Climate Change. Cambridge: Cambridge University Press.
- Strobl E, Valfort M. 2015. The effect of weather-induced internal migration on local labor markets: evidence from Uganda. *World Bank Economic Review*, 29(2), 385-412.
- Sudmeier-Rieux K, Fernández M, Gaillard JC, Guadagno L, Jaboyedoff M. 2017. Introduction: Exploring Linkages Between Disaster Risk Reduction, Climate Change Adaptation, Migration and Sustainable Development. In K. Sudmeier-Rieux, M. Fernández, I. M. Penna, M. Jaboyedoff & J. C. Gaillard (Eds.), *Identifying Emerging Issues in Disaster Risk Reduction, Migration, Climate Change and Sustainable Development: Shaping Debates and Policies* (pp. 1-11). Cham: Springer International Publishing.
- Tacoli C. 2009. Crisis or adaptation? Migration and climate change in a context of high mobility. *Environment and Urbanization*, 21(2), 513-525. doi: 10.1177/0956247809342182
- Thiede B, Gray C, Mueller V. 2016. Climate variability and inter-provincial migration in South America, 1970–2011. *Global Environmental Change*, 41, 228-240. doi: <https://doi.org/10.1016/j.gloenvcha.2016.10.005>
- Trenberth KE, Dai A, Van Der Schrier G, Jones PD, Barichivich J, Briffa KR, Sheffield J. 2014. Global warming and changes in drought. *Nature Climate Change*, 4(1), 17.
- UN. 2016. New York Declaration for Refugees and Migrants. <https://refugeesmigrants.un.org/declaration>. Accessed December 2019.
- UNDESA. 2017a. International Migration Report 2017 United Nations, Department of Economic and Social Affairs, Population Division
- UNDESA. 2017b. Trends in International Migrant Stock: The 2017 Revision from United Nations, Department of Economic and Social Affairs, Population Division <https://www.un.org/en/development/desa/population/migration/data/estimates2/estimates17.asp>
- UNDESA. 2017c. World Population Prospects: The 2017 Revision, Key Findings and Advanced Tables *Political geography*: United Nations, Department of Economic and Social Affairs.
- UNDESA. 2017d. World Population Prospects: The 2017 Revision. Data: United Nations, Department of Economic and Social Affairs.

- UNDESA. 2019. Child and Young migrants. <https://migrationdataportal.org/themes/child-and-young-migrants>. Accessed on 4 January 2020.
- UNDP. 2009. Human development report 2009: overcoming barriers-human mobility and development: United Nations Development Program.
- UNECA. 2017. African migration: drivers of migration in Africa. Draft Report Prepared for Africa Regional Consultative Meeting on the Global Compact on Safe, Orderly and Regular Migration. Addis Ababa, Ethiopia: United Nations Economic Commission for Africa
- UNHCR. 2018. New York declaration. Task Team on Comprehensive Responses, UNHCR Headquarters, Geneva www.unhcr.org/newyorkdeclaration
- Warner K, Erhart C, de Sherbinin A, Adamo S, Tricia C. 2009. In search of shelter: mapping the effects of climate change on human migration and displacement. CARE Rep. http://issuu.com/careandclimatechange/docs/care_in_search_of_shelter
- Warner K, Hamza M, Oliver-Smith A, Renaud F, Julca A. 2010. Climate change, environmental degradation and migration. *Natural Hazards*, 55(3), 689-715.
- Woolf D, Solomon D, Lehmann J. 2018. Land Restoration in Food Security Programmes: Synergies with Climate Change Mitigation. *Climate Policy*, 18, 1260-1270.
- World Bank. 2010. Development and Climate Change. World Development Report 2010.
- Wrathall DJ, Suckall N. 2016. Labour migration amidst ecological change. *Migration and Development*, 5(2), 314-329. doi: 10.1080/21632324.2015.1022967
- WRR. 2017. World Risk Report: Analysis and prospects 2017. UNU-EHS and Bündnis Entwicklung Hilft.
- Yang W, Seager R, Cane MA, Lyon B. 2015. The annual cycle of East African precipitation. *Journal of Climate*, 28(6), 2385-2404.
- Zhang YJ. 2018. Culture, institutions, and the gender gap in competitive inclination: evidence from the communist experiment in china. *The Economic Journal* (Accepted Author Manuscript). doi: 10.1111/ecoj.12596
- Zilberman D, Zhao J, Heiman A. 2012. Adoption versus adaptation, with emphasis on climate change. *Annual Review of Resource Economics*, 4, 26-53.



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