POPULATION GROWTH, CLIMATE CHANGE AND PRESSURE ON THE LAND

Eastern and Southern Africa

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Population Growth, Climate Change and Pressure on the Land[1]

1.1. Introduction

Across East and Southern Africa, many factors drive vulnerability, resilience, and adaptation in food systems. Climate change is one of the most significant synoptic drivers of change in these conditions across the region. This document provides guidance regarding significant issues emergent from the current climate change, population, agricultural, and land use and cover change literatures. Our purpose here is to clearly present to a broad audience the most pressing gaps in knowledge, methods, and data that stand as obstacles to improving food security under climate change conditions. The document is organized with a summary of findings further structured as deliverables followed by specific support for these items. The guiding research questions below are those topics we find compelling, potentially innovative, and are definable or tractable. The sections include: 1.2) guiding research questions, 1.3) agricultural innovations, 1.4) climate change and assessments, 1.5) pressures on water resources, 1.6) pressures on land, 1.7) population and migration, 1.8) gender, 1.9) a programmatic review of the GCFSI relationship with existing and recently concluded USAID projects, and 1.10) references.

1.2. Guiding Research Questions

a. **Agricultural Innovations**: Innovations to support food security in a changing climate, with a focus on production systems, and the potential for sustainable intensification and/or sustainable extensification of those systems across Eastern and Southern Africa. The **deliverable** would be a formal assessment via an agricultural systems framework of maize-based farming, or other equivalent significant system, in the region. ***Research question***: *How can agricultural systems analysis be applied to diagnose constraints, opportunities and scalability of innovations to support resilient and sustainable farming?*

b. **Climate Change and Assessments**: Integrated assessments and / or models designed to estimate uncertainty in the climate / agricultural / human decision-making system, and to identify possible areas to reduce uncertainty for a) livestock systems, and b) cropping systems at local and regional scales. The **deliverables** should include: an assessment of the current state of crops or livestock, climate, land use, and human decision making/management models; an exploration of the sensitivities of the combined systems that evaluate uncertainty or risk under plausible future climate scenarios; design at local to regional scales and continuous model spaces. This deliverable could include the identification of thresholds/tipping points or of transformational adaptive states where food production risk or food security risk is significantly reduced. ***Research questions****: Is it possible to construct significantly better uncertainty* *estimates for food production and food production risk by developing integrated social/crop/livestock/climate models? Do alternative crop/livestock/climate/socioeconomic states exist that can be reached through transformational adaptation (Kates et al. 2012)? Do local solutions scale regionally or across agro-ecological zones?*

c. **Pressures on Water Resources**: Document existing small-scale irrigation technologies being practiced in East Africa. **Deliverables** could compare the advantages and disadvantages of small-scale irrigation technologies; identify technological/social/economic problems concerning implementation and adoption of small-scale irrigation technologies; recommend socially acceptable and economically viable small-scale irrigation technologies for upscaling; identify the intervention measures required for the large-scale adoption of recommended small-scale irrigation technologies; estimate adoption costs in different regions; develop design criteria for recommended small-scale irrigation systems; identify areas best suited for adoption with respect to sustainability, e.g. groundwater resources. ***Research Question***: *Is it possible to significantly reduce vulnerability and increase resilience of small-holder agriculture in East and Southern Africa through the design and implementation of small-scale irrigation projects?*

d. **Pressures on Land**: Synoptic, reliable, and accurate land use and cover data particularly focused on arable lands is necessary for vulnerability management, effective crop modeling, and as a base layer for regional climate models. **Deliverables** include methods for the efficient production of accurate arable lands data for Eastern and Southern Africa. Any products should demonstrate accuracy particularly for agricultural classes, with special emphasis on maize, currency, repeatability with existing or planned satellite platforms, and synoptic coverage. ***Research Question***: *Where are the arable lands of East Africa? Where are the marginal arable lands? How might climate changes improve or degrade arable and/or marginal lands?*

e. **Population and Migration**: In the East African context, more reliable data are needed on: who engages in rural-urban migration; household- and community-level effects of urban remittances on agricultural practices that respond well (or not) to climate changes; analysis and policy actions to understand migration as a gendered process and how that affects food production through analyzing different patterns, drivers and impacts on men and women, and the relationship between the role and status of women in the region and gendered migration; effective resettlement assessments to include well-being/quality of life of pre- and post-resettlement. **Deliverables** might include: better measures of population movements over space and time to include spatial models or mapping solutions; development of rural-urban resource networks to improve how agricultural practices in sending communities respond to climate change; innovative solutions to strengthen migrant social networks at rural origins and its impact on agricultural production; innovative solutions to re-establish social networks at urban destinations and how that can be a source for economic development both at sources and destinations; policy actions to address social practices that discriminate against migrants based on gender and other social/cultural norms; measures to address the misallocation of resources for effective resettlement, including quality of life indicators. ***Research questions:*** *How can we develop/enhance the equitability of migration, especially those that incorporate gender, to increase the economic viability and adaptation of vulnerable populations and households. How do we best empower migrants, especially rural-urban migrants, through social networks to achieve economic viability?*

f. **Gender:** The primary goal is the inclusion of gender analysis into the design of climate change and agriculture related research in Southern and Eastern Africa. Gender analysis is a methodology that systematically organizes and interprets information about gender relations. Particularly important for gender analyses is the collection of sex-disaggregated data (Habtezion, 2012). **Deliverables**: 1) A desktop review of current sex-disaggregated data on gender and climate change in East Africa. 2) A sex-disaggregated dataset at the household and community level with information on the division of roles and responsibilities, ownership of assets critical to climate change (e.g. land and livestock), adaptation practices and mitigation strategies. Qualitative methods such as focus groups and participatory action research should be used to collect supplemental information for an in-depth understanding of the realities that men and women farmers face when it comes to climate change. 3) A gender analysis to identify gender-based constraints, and eventually link the gender based constraints to gender differentiated climate change adaptation practices and impacts. **Research question**: *In the context of East Africa, how do gender differences in roles and responsibilities and the gender gaps in climate change related resources: 1) influence gendered perceptions of climate change; 2) create gender differences in climate change adaptation strategies; and 3) result in gender differentiated impacts and vulnerabilities.*

1.3. Agricultural Innovation

Stagnation characterizes agricultural development and research across Eastern and Southern Africa, with local exceptions and hot spots of opportunity (Markwei et al., 2009). Adding to this situation are new challenges and opportunities posed by a growing population and the uncertainty of a changing climate (Moore et al., 2012). Smallholder farming systems are crucial to food security and development prospects for this region and are particularly at risk to climatic variability such as poorly timed dry spells, extended drought and excess rainfall (Funk et al., 2008). In this complex and changing environment, technical solutions have frequently failed. Participatory action research has provided notable exceptions, including introduction of crop varieties and integrated agricultural management tailored to local requirements (Snapp et al., 2010; Tittonell et al., 2012). A systematic systems analysis and co-learning approach with local communities has supported the identification and rapid adoption of best bet options, sometimes called plausible innovations, yet impact at larger scales remains rare (Giller et al., 2006). A promising approach is to engage participatory and simulation modeling with action research as a means of scaling out (up); however, the challenge of linking approaches remains (van Wijk et al., 2012). How can we target innovations to socio-economic and biophysical environments where they are well suited, test performance over time and space with communities, and support local adaptation?

Understanding farming systems and applying decision support tools, including models, is fundamental towards building capacity for adaptation, locally and across the region. This can support the innovation, experimentation and information sharing that leads to adoption and more resilient farming techniques (O'Brien, 1998). Farmers' preferences often value traits such as stability of production, meeting a diversity of requirements, labor and land saving traits, and locally-preferred taste and storage traits above metrics of productivity, such as high yield (Ceccarelli and Grando, 2007; Mugwe et al., 2009). 'Plausible bet' technology options have been identified that show promise as means to improve soil moisture, holding capacity and drought resilience, to support farmer innovation, but these options need to be tested and scaled out over space and time, in an often risky climate and marginal production environment (Snapp and Heong, 2003).

There is an increased recognition that a systems approach links farming system simulation models to participatory engagement can help meet the challenges presented by highly heterogeneous and complex farming systems (McCown et al., 2009). Robust case studies are required to test the crop simulation modeling approaches linked to participatory research as a foundation for farming systems analysis to expedite knowledge accumulation in complex environments. The next steps needed include agricultural systems diagnosis to identify 'best bet options' and modeling of performance within a farming systems context with participatory feedback by Eastern and Southern African farm communities and extension advisors. Case studies are urgently required of participatory action research approaches linked to simulation modeling, dynamic systems or participatory modeling to provide insights into climatic risk, adaptation potential, and how to drive agricultural intensification in a manner that supports local resilience.

USAID has previously funded projects that may appear to overlap with these goals. The most obvious is Africa RISING (Research In Sustainable Intensification for the Next Generation), a research initiative of Feed the Future, which supports farming communities to sustainably intensify production and reduce poverty. Three regions are targeted by Africa RISING, with West Africa (Ghana, Mali) and East Africa (Tanzania, Malawi) research being led by the International Institute of Tropical Agriculture (IITA), and the Ethiopia highlands led by the International Livestock

Research Institute (ILRI). The overall goal is to define an integrated research for development (R4D) model that is scaleable and adaptable. Viable pathways for sustainable intensification of cereal-legume-livestock systems are under development, with attention to differentiation of households by resource endowment, gender-awareness, and conservation of the environment. In addition to comprehensive monitoring and evaluation exercises, promising integrated technologies and participatory approaches to R4D have been inventoried for the three regions, and on-farm research is underway in rural communities in key regions and farming systems, chosen to align closely with USAID mission priorities. In contrast, the Global Center for Food Systems Innovations (GCFSI) focuses on 'big picture' problem definition and identification of research opportunities to source innovations and address knowledge gaps. Many outputs catalyzed or produced by GCFSI will have clear relevance to research underway in the Africa RISING program. These include examples such as drivers of sustainable intensification identified through agricultural systems analysis, improved land use information for the target regions, and delineation of pathways towards identifying and deploying irrigation innovations, both technical and institutional. As Africa RISING iteratively engages in action research and development activities, analysis of key problems and identification of innovation solutions will be areas where GCFSI can provide support. Lessons learned by Africa RISING can also contribute and feed into enabling GCFSI to understand the scope and importance of problems and help identify or test potential winning innovations.

Intractable and well-known problems

- How to target innovations
    - Lack of reliable data on land use and farming systems
    - Heterogeneity of resources, farmer priorities, constraints and opportunities vary over space and time confounding abilities to target
    - Fine-scale targeting to specific socio-economic and environmental conditions leads to overly complex recommendations that do not take into account a rapidly changing world.
- How to support local adaptation and adoption of innovations
    - There is limited capacity to link indigenous knowledge with science-based evidence on innovations.
    - Participatory education approaches are resource-intensive and often local in scale; how is support provided for adaptation at scale, in order to reach millions of smallholder farmers and other stakeholders?

Intractable but lesser-known problems

- How to evaluate success of innovations
    - Metrics of success are sparse and highly contested, a barrier to monitoring and judging progress.
    - Gender-aware metrics are not widely used beyond simplistic enumeration by gender.
- Scaling out innovations in a changing world with highly variable weather and markets
    - Attention to scale is urgently required in problem characterization and support for innovation development.

- Data sets are required that are formulated for use in a rapidly changing context.
- More attention is required to analyzing risk and diverse scenarios.

Novel ideas that might be actionable

- Agro-ecological knowledge could be more fully utilized to target innovations through developing 'best bet' innovations that could form the basis for local adaptation and adoption.
- Participatory action research and modeling are promising approaches that could be integrated to support agricultural systems analysis, for testing and scaling out of innovations in a changing world.
- Communication among stakeholders – policy makers, researchers, extension educators, community member and land managers - could be enhanced through participatory modeling and scenario visioning.

1.4 Climate Change and Assessments

Climate change is increasing variability in rainfall. This shift increases uncertainty in crop production for humans and forage production for livestock. Uncertainty is central to assessing food security risk; since the climate of East and Southern Africa is demonstrably non-stationary, stakeholders and policymakers need an integrated assessment of how climate, crops and socioeconomic systems currently interact and how they might interact under a variety of higher-risk future scenarios. Rainfall amounts, distribution, and intensity are changing throughout East Africa. Regions with bimodal (two rainy seasons) seasonality are showing more frequent failures of one of the rainy seasons, causing droughts (insufficient rainfall, rainfall failing during critical growth periods), floods, and more frequent torrential/heavier rains. The change in timing and duration of crop growing seasons reduces the reliability and yields of food production.

East African cultivation already is shifting due to climate change with significant changes projected into the future (Figure 1.4.1).

Cereal productivity in Sub-Saharan Africa under a scenario of the IPCC that shows CO_2 atmospheric concentrations a level at 520-640 ppm by 2050

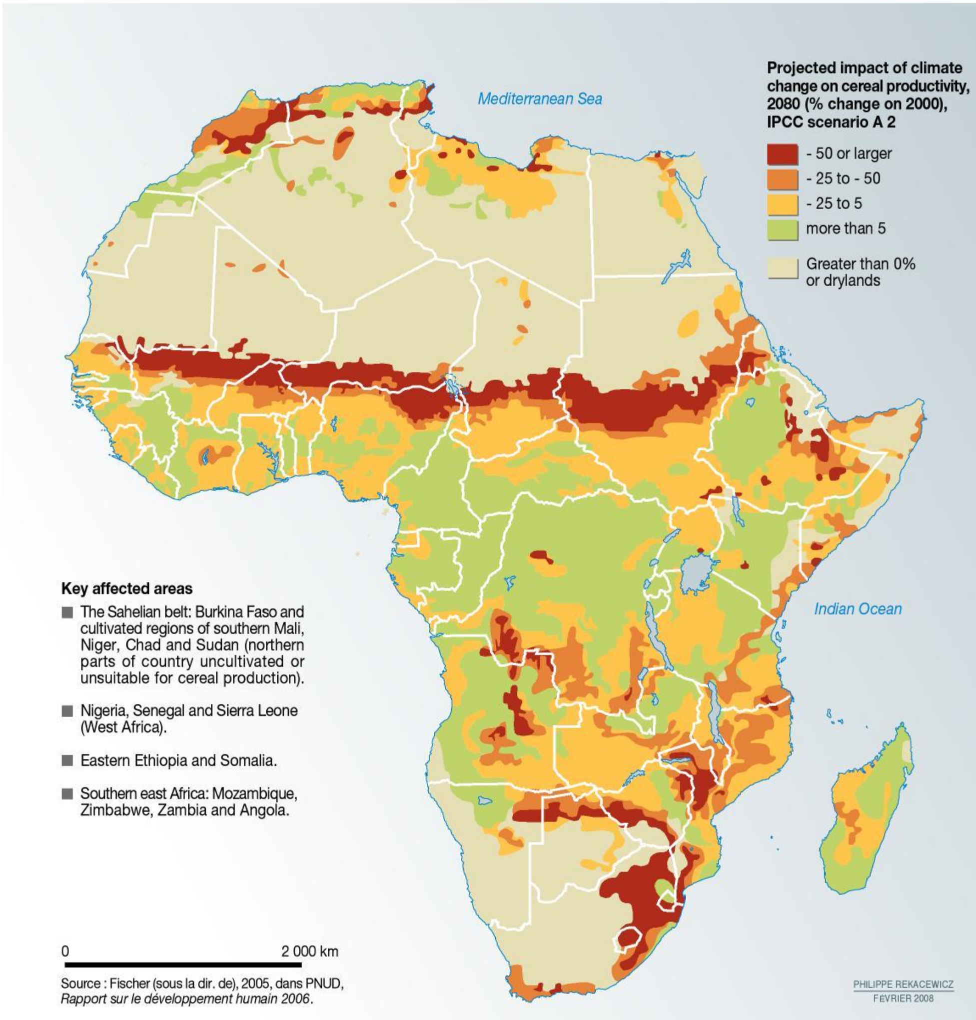


Figure 1.4.1.

Several scientific studies have sought to characterize food insecurity and to identify likely regions of risk but with contradictory results. Lobell et al. (2008) find that for East Africa's main crops, especially maize, food security will show almost no change by 2030 and that yields in 2030 will be largely the same. However, Lobell et al. (2011) conclude the opposite — that "roughly 65% of present maize-growing areas in Africa would experience yield losses for 1 °C of warming under optimal rain-fed management, with 100% of areas harmed by warming under drought conditions." Figure 1.4.2 below, from Lobell et al. (2011), shows yield declines for sub-Saharan Africa and identifies large swaths of the East African regions as prone to declines of 20% or greater in historically cropped areas. Identifying these thresholds of decline is crucial to developing interdictions strategies. In general, ecologists observe that identifying critical thresholds (Thornton et al. 2011) is crucially needed for when cropping/livestock systems have water stress, nitrogen stress, and need for diversification strategies.

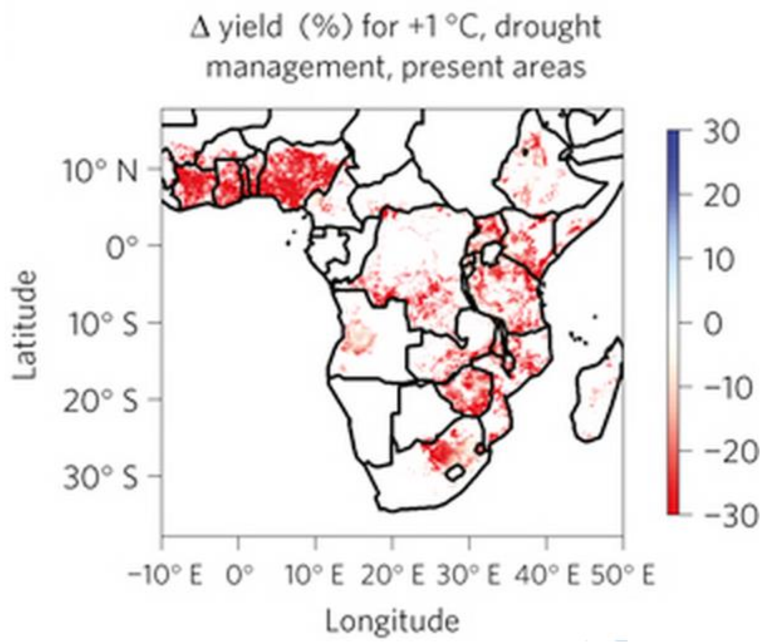


Figure 1.4.2. Changes in yield projected for a 1°C increase in temperature.

Warmer temperatures in low-altitude regions are leading to foreshortened growing seasons; grasslands respond to reduced rainfall and higher temperatures with lower forage; migration is altering the rural labor supply and, thus, yield; high-altitude agro-ecological zones are showing improved maize yields, but this is insufficient to offset losses at lower elevations. These climate changes also have the potential to change pest, disease, and weed growth as well. In particular, we need to integrate human decision making to understand variability in management/cultivation into crop-climate or livestock-climate models (Thornton et al. 2009). These are the so-called "agricultural impact models" that not only make predictions but, more importantly, characterize our understanding of coupled systems. When these models fail to replicate reality, science learns something.

Climate change creates the problem of increased insecurity and increased uncertainty in food production. However, it creates the opportunity to explore a diversity of lower-risk integrated social/crop/climate systems. What multi-year combinations of livestock, crop, and social systems will better withstand near-term projected climate changes? Livestock is a major part of food production in East Africa, yet integrated assessments of climate, livestock, and human decision-making are woefully underrepresented. Very little work has been done on livestock modeling and its production uncertainty under climate change; it is only briefly discussed in the IPCC AR4 documentation. In particular, there is a need to understand "nature and extent of the tradeoffs possible between different crop and livestock enterprises" (Thornton et al. 2009). Given livestock's importance for East Africa's savannas, we need to understand the uncertainty of changes in grassland productivity, the uncertainty in meat production, and the uncertainty of where and how land use complicates this picture.

There is little agreement about vulnerability and productivity changes. The previous two maps from Fischer (Figure 1.4.1 and 1.4.2) and Lobell illustrate the extreme uncertainty in climate projection models. More economically based projections (Figure 1.4.3) and projections based on vulnerability indexes (Figures 1.4.4 and 1.4.5), show even more divergent futures for East Africa. Are any of these models correct? How can we determine this in the face of additional changes in population, land management, and global economic activity?

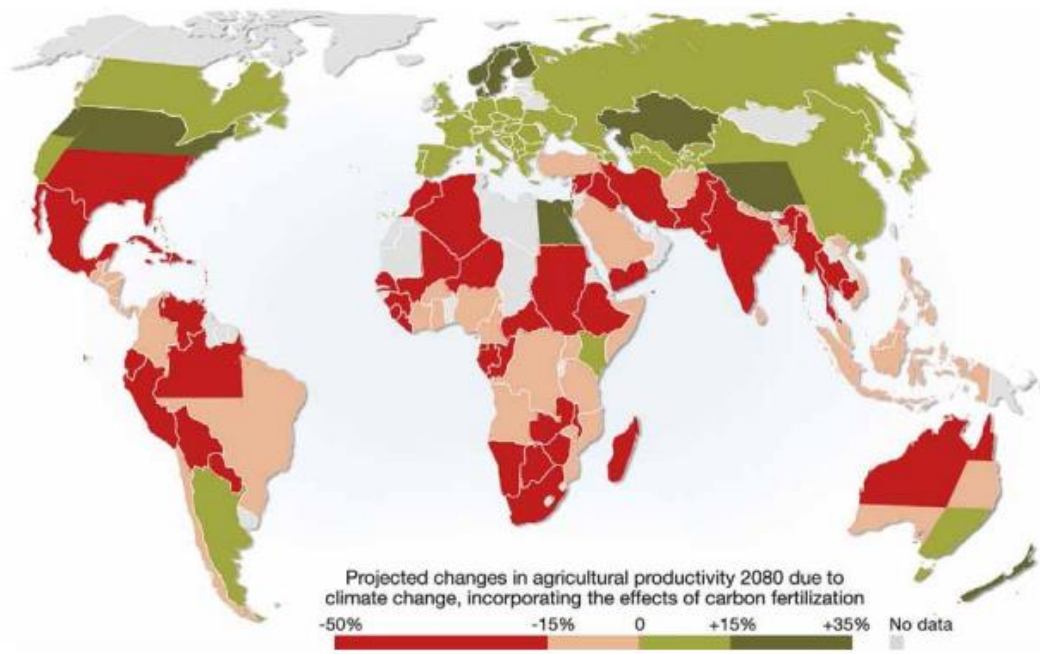


Figure 1.4.3. Changes in agricultural productivity for 2080. From Cline (2007).

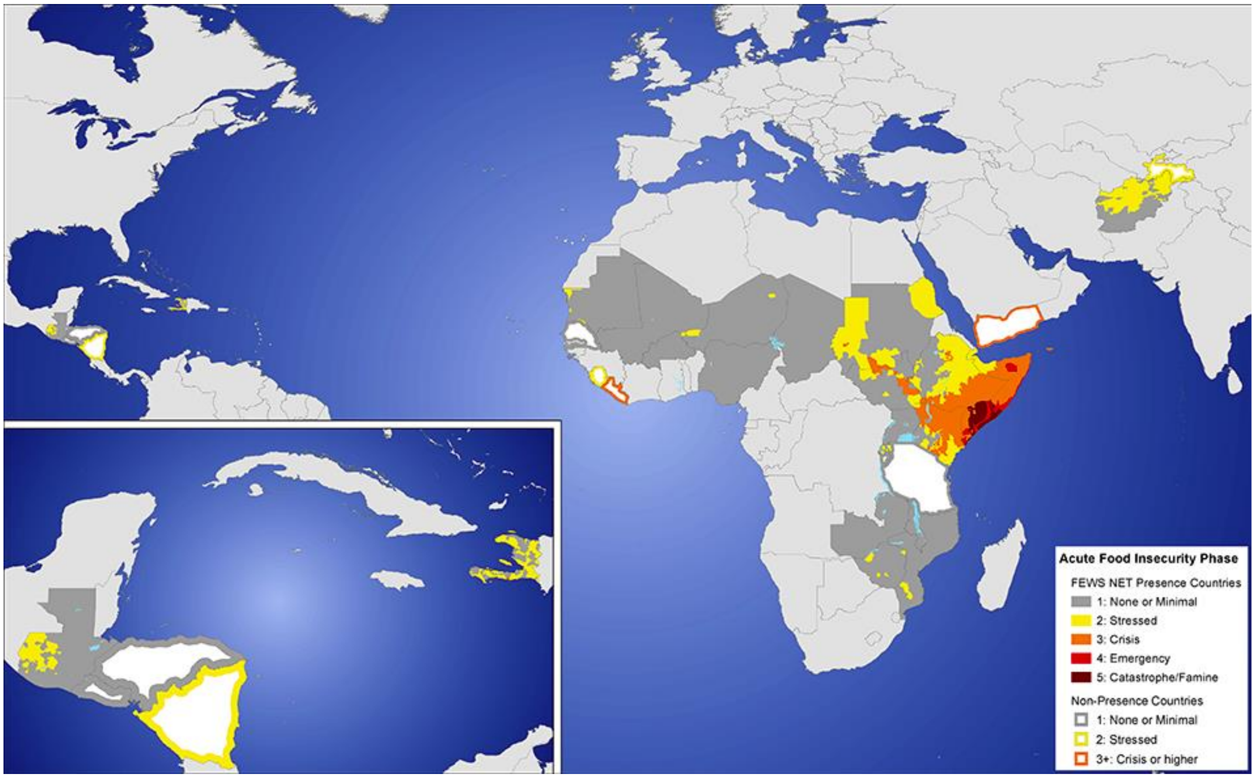


Figure 1.4.4. Food Insecurity for 2011. FEWSNet: www.fews.net

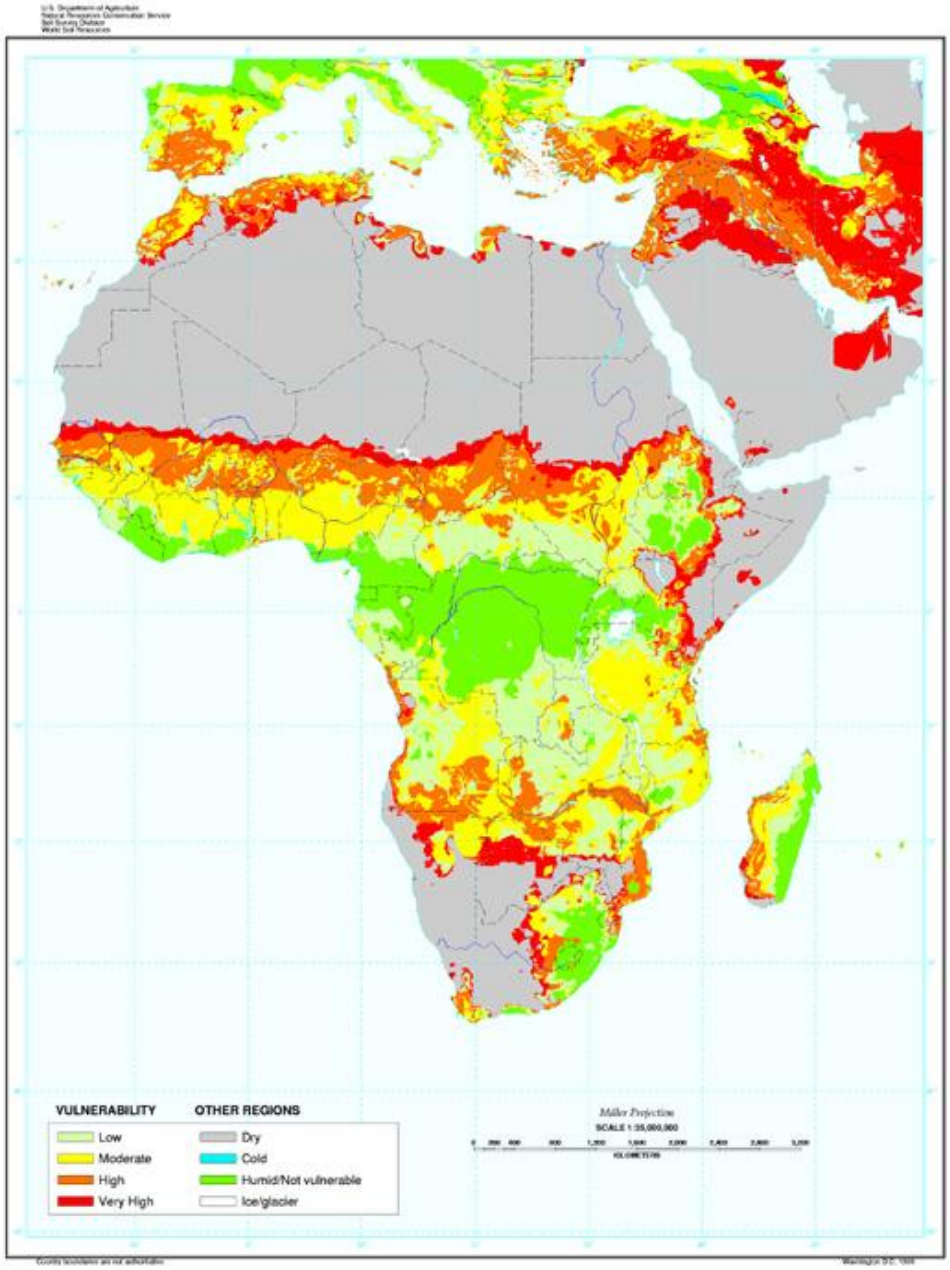


Figure 1.4.5. USDA Crop vulnerability. From Reich et al. (2001).

Crop modeling in East Africa has drawn more attention, but crop models that integrate human management and decision-making are lacking at regional and local scales. Nation-level assessments and models assume that the mean represents the distribution where such assumptions are not valid and certainly do not represent food-insecure populations. High resolution coupled socioeconomic crop-climate simulations would enable household level studies to develop adaptation and mitigation strategies for poor households (Challinor et al. 2013). Work on quantifying and reducing uncertainty is particularly needed. Lastly, we need to identify critical thresholds (Thornton et al. 2011) for when cropping/livestock systems encounter failure: water stress, nitrogen stress, inadequate productivity, and the need for diversification strategies.

Since East African farmers typically use multiple cropping systems interconnected with livestock systems, the focus should be on several major crops. First, scientists need to understand and calculate the limitations / uncertainty envelopes of crop models. Next, estimates are needed of how each of these crops will respond to likely climate changes. Finally, we need to test these coupled models for sensitivity to a variety of conditions (Boone et al. 2011). Recent developments in remote sensing tools have shown that variability and trends in NDVI can be useful as a check on historical patterns of crop production for East Africa (Vrieling et al. 2011). These techniques combined with crop-climate models, should allow us to identify high variability (marginal) lands, areas for conservation, and areas suitable for crop intensification. The scientific community should aim to predict regions prone to deforestation. Overall, an integrated impacts assessment across several food production strategies should seek "triple-win" strategies of adaptation + mitigation + profitability (Bryan et al. 2013). Higher-resolution studies (e.g. Moore et al. 2012) can also assist in identifying potential areas for agricultural expansion or intensification (Figure 1.4.6).

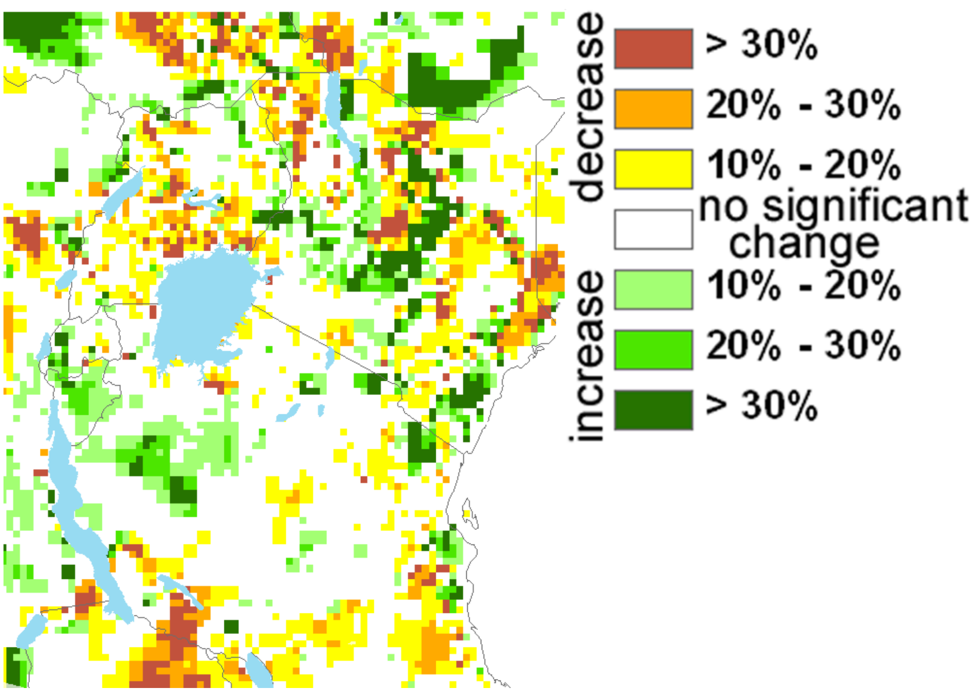


Figure 1.4.6. Projected percentage change in maize yields under land cover change and climate change. From Moore et al. (2012).

Modeling efforts typically do not explore pests/diseases for cropping systems or livestock systems; there is too much uncertainty. The current state of pathogen modeling capabilities is no better than chance, so work needs to focus primarily on crop-climate models and on better understanding both the coupled system uncertainty and the model-internal uncertainty. Since impact assessments require both estimates of future productivity and error bounds, we propose the use of coupled models to clarify thresholds, limits, and tipping points. This will offer targets for field studies and crop trials to test (Craufurd et al. 2013). High resolution fully interactive processed based climate–crop models offer an avenue of approach to this problem.

Much of East Africa's land use is devoted to pastoralism. Given a highly variable climate, livestock is an optimal choice for most years; rangeland productivity is quite high and a very good source of calories for livestock and wildlife. Datasets for quantity, type, and nutrition already exist (Ekaya 2011) and hold the potential for longer-term simulations for future projections. There are a handful of ecosystem models developed for East Africa's particular systems, including SAVANNA and RUMINANT. Other models like CENTURY, at Colorado State University, have been adapted for use in the region. As with crops, the scientific community needs to improve calculations for the suitability of livestock in many areas of East Africa. Models addressing changes in food chains due to climate change across livestock/climate change connections are not well known; in addition, there is a lack of livestock monitoring and research investment (Kruska et al. 2003). Some data are available for grassland productivity estimates (Kinyamario 1996), and these datasets can be used in models like CENTURY, RUMINANT, and SAVANNA for calculating the productivity of non-cropped and marginally cropped land. These tools can be used not only for estimates of livestock production (Figure 1.4.7) but also to understand what limits exist for animals versus crops — and to develop standards for land use management strategies (Reid et al. 2006).

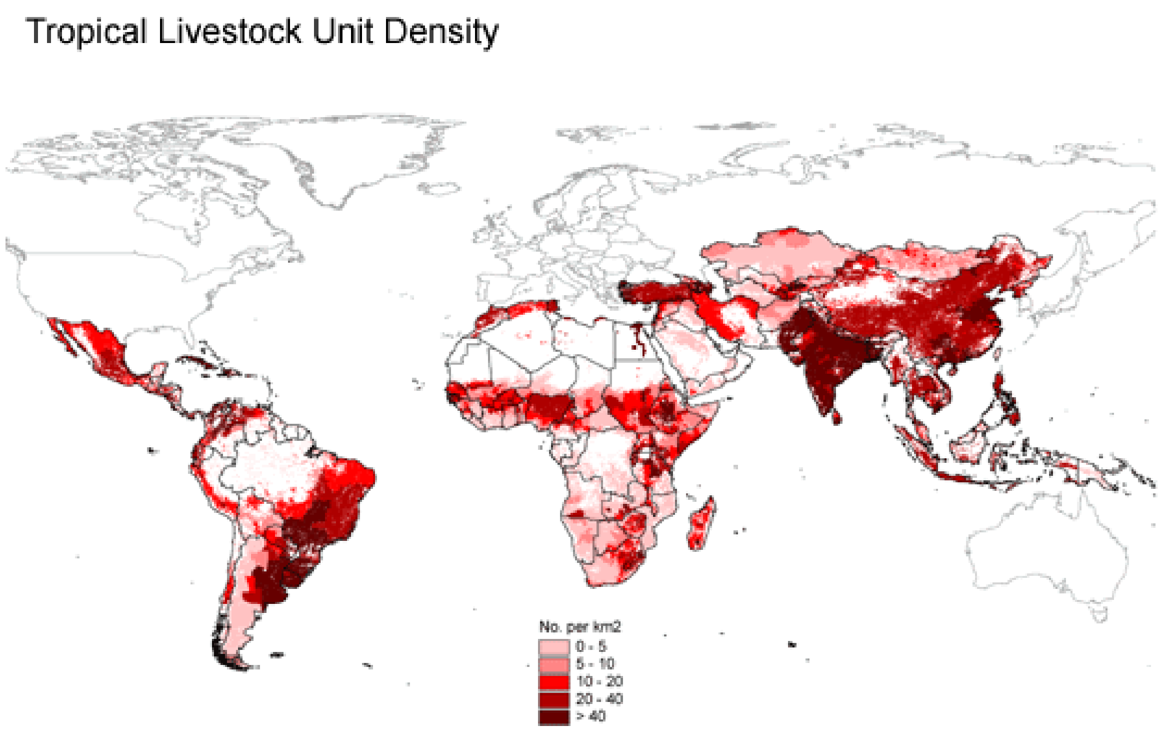


Figure 1.4.7. Tropical Livestock Unit Density. From Thornton et al. (2002).

High resolution coupled socioeconomic crop-climate simulations enable household level studies of food security, but these models can arrive at conclusions that omit the role of alternative, back-up food systems common in marginal areas that include small livestock, food storage, and the informal economy. Integrated assessments will ultimately need to include not only food production but also food distribution related to infrastructure and access to markets. These are fundamentally geographic problems where spatial distribution of people plays a strong role in determining levels of food security. Models also need to account for alternative crops that are more likely to be relied upon if maize or rice crops fail, such as sweet potato, teff, millet, cassava, and many others.

To further this, much better maps are needed to estimate the total land under cultivation, but this is very complicated because of the way mixed agriculture is done in East and Southern Africa (Fritz et al. 2013). The best maps of land use for East Africa are based on 20-year old data (i.e. Africover). Ultimately, assessments need to know where food is being grown in order to measure the connection between climate variability and the stability of food supplies for vulnerable people (Schmidhuber and Tubiello, 2007). Assessing food security under climate change is like definitions of sustainability; it is hard to identify until it fails because so many elements are connected together. "Climate change is only one of several changes affecting food systems and that its relative importance varies both between regions and between different societal groups within a region. Adaptations of food systems via interventions in availability, access and utilization are possible to cope with climate change at different scales although their feedbacks to the earth system have yet to be fully assessed" (Gregory et al. 2005). Better-integrated models will help to illuminate the misperceptions and the uncertainties in our perceptions of food security and food production risk. Simulation methods that integrate climate and human behavior provide a novel approach to understanding adaptation options for climate variability and change (Slingo et al., 2005).

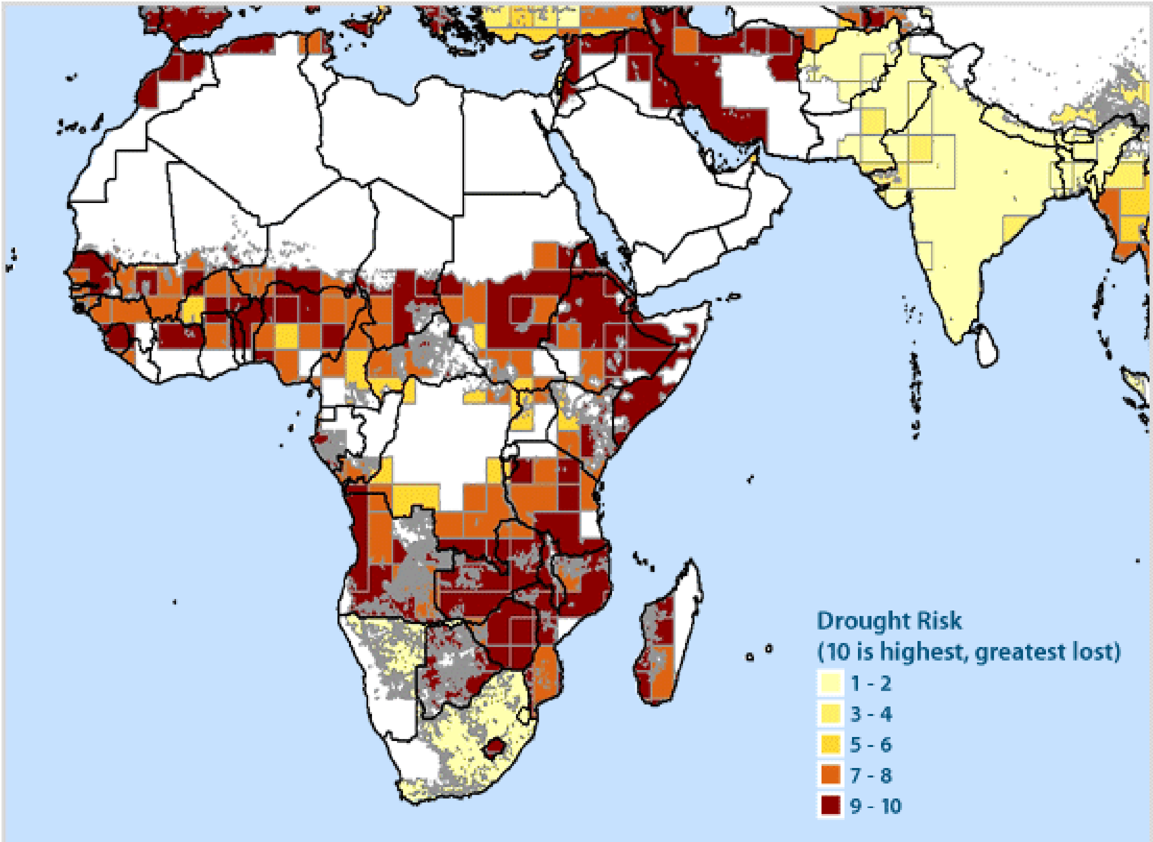


Figure 1.4.8. Drought Risk for tropical cropping systems. From Arnold (2006).

As an example, Figure 1.4.8 shows drought risk for Africa, illustrating one of the main risks for rain-fed crops in sub-Saharan Africa. Thornton and Cramer (2012) point out that "The impacts of climate change on rice production and productivity can be summarized by the following factors: heat stress, increased night-time temperature, flooding, drought, and salt stress." Implicit in these factors is climate but also crop choice, land use, access to technology, water rights, and a host of complications. Drought can be meteorological, agricultural, hydrologic, or economic. Understanding how these aspects couple together now and what thresholds exist now and in the future forms the basis of where food security research needs to be because "…the solution is found in **research and development** to assist farmers to improve current farming practice, largely on existing agricultural land (Connor & Mínguez 2012)."

Intractable and well-known problems

- Low density of weather station data
- Low availability of high resolution rainfall data (e.g. Nexrad)
- Lack of readily available regional or statistical downscaling
- Lack of irrigation infrastructure and reliance on rainfall
- Lack of water storage capacity

Intractable but lesser-known problems

- Intra-seasonal rainfall variability and short-term dry spells may also substantially reduce crop yield
- Lack of projections for specific cash crops (e.g. tobacco, tea, sugar)

1.5 Pressures on water resources

Across Africa, the United Nations is projecting a population increase from about 1 billion in 2011 to over 2 billion in 2050 and over 3 billion in 2100 (UN, 2011). With this increased population, one implication of the changing climate is that rising temperatures will not only increase food and water stressors but also increase broader population scale water insecurity. For example, by 2025 Kenya, Rwanda and Malawi are projected to have less than 1000 m^3/person/year of available potable fresh water and Ethiopia, Tanzania, Mozambique, and Uganda will have between 1000-1700 m^3/person/year (Bates et al., 2008). Changes in rainfall variability over space means that although some areas will experience increases in rainfall, many will receive it in the form of intense precipitation events, especially in tropical and high-altitude regions (Bates et al., 2008).

1.5.1 Climate change impacts on water resources and implications

Variability in precipitation timing, amounts, and an increase in evapotranspiration alter available soil moisture, directly affecting crop production (Bates et al., 2008). Temperature and precipitation variability will not only affect crop yields but also the suitability of land for particular crops (Tables 1.5.1. – 1.5.8.). For example, as a result of an increase in temperature, the area suitable for tea production in Uganda is expected to decrease substantially by 2050, and the optimum production elevation will move upwards from 1450-1650 meters to 1550-1650 meters above sea level (CIAT, 2011). Annual or seasonal rainfall variability affects agricultural productivity, while intra-seasonal rainfall variability and short-term dry spells may also substantially reduce crop yield if it occurs during reproductive growth stages (MNREE, 2011).

Changes in runoff and river discharge rates will affect existing and potential irrigation schemes, along with water levels in receiving lakes and reservoirs (Table 1.5.9). The projected rise in sea level will salinize groundwater and increase the vulnerability of freshwater resources, drinking water wells, and water treatment works in coastal megacities (Elliot et al., 2011). Decreases in annual precipitation and/or changes in timing, intensity, and duration of rainfall events are expected to impact shallow aquifers, especially in areas with a single, long dry season (Calow and MacDonald, 2009). Fortunately, groundwater recharge is unlikely to decrease by more than 10% in areas that have high population density until the 2050s (Döll, 2009). Impacts to the quality and quantity of water in lakes may also affect the existing fishery industry. Currently, fisheries contribute 4% to the national Gross Domestic Product in Malawi, and, if the fishing industry is impacted by climate change, more people will be forced to return to agriculture, which ultimately increases pressure on the land (MNREE, 2011).

Table 1.5.1: Variability in temperature and rainfall in Ethiopia predicted by different climate models under different climate scenarios

Region	Model	Scenario	Temperature		Rainfall	Year	Reference
			Max	Min			
Lake Ziway Watershed	HadCM3 GCM model	A2, B2	+3.6-4.2°C	+1.95-2.0°C	Up to +29% (Annual) Up to +9.4% (Monthly)	2099	Zeray et al. (2006)
Gilgel Abay catchment in Lake Tana basin	HadCM3 GCM model	A2 B2	+1.4°C +1.1°C	+2.2°C +1.7°C	May-June: decrease Sept-Oct: increase	2050	Abdo et al. (2009)
		A2 B2	+2.5°C +1.8°C	+3.7°C +2.7°C	June: -18.0% A2, -11.2% B2 Sept: +8.5 A2, +5.7 B2	2080	
Ethiopia	CCCM GFDL UKMO-89 GFDL-Transient		+ 0.5 -3.6°C		Kiremt: +10 to 50% (transient model projected decrease) Belg: 5% increase (decrease in north) Bega: General increase		MWR (2001)
Ethiopia	MAGICC/SCENGEN/ Regional and global Climate SCENario GENerator	A1B	+0.9-1.1°C		+1.4-4.5%	2030	MWR (2007)
			+1.7-2.1°C		+3.1-8.4%	2050	
			+2.7-3.4°C		+5.1-13.8%	2080	
Ethiopia	ECHAM4/ OPYC3 HadCM3 CSIRO-Mk2 CGCM2 GFDL-R30 CCSR/NIE	A2	+3.84°C		-3.4%	2070-99	Cline (2007)

Region	Model	Scenario	Temperature		Rainfall	Year	Reference
			Max	Min			
	S						
Ethiopia	PCM, CGCM2, CSIRO2, HadCM3, ECHam4	A2 B2	+2.3-3.8 +2.3-4.0		-13% -+12% -13%-+12%	2050	Strzepek and McCluskey (2007)
		A2 B2	+5.5-9.4 +3.8-6.7		-28% -+32% -28%-+32%	2100	

Table 1.5.2: Variability in temperature and rainfall in Kenya predicted by different climate models under different climate scenarios

Region	Model	Scenario	Temperature	Rainfall	Year	Reference
Kenya	11 models	Doubling CO_2	+2.6°C -4.2°C (daily)	-20%-+20%	2075	ROK (2002)
Western Kenya	CCSR96 CSI296 ECH498 GFDL HAD300	A2	+0.6-1.7°C	-14.6-+48.6 (monthly variation)	2050 (2020 as baselin e)	Githui (2008)
		B2	+0.9-1.7°C	-16.0-+37.0 (monthly variation)		
Kenya	ECHAM4/OPY C3 HadCM3 CSIRO-Mk2 CGCM2 GFDL-R30 CCSR/NIES	A2	+3.5°C	+8.4%	2070-99	Cline (2007)
Kenya			+1°C -+3.5°C	Uncertain		SEI (2009)
Kenya	CCC	Doubling CO_2	+3.5°C	-20%	2030	Kabubo-Mariara and Karanja (2007)
	GFDL		+4°C			
Kenya	PCM, CGCM2, CSIRO2,	A2 B2	+2.2-3.6 +2.3-3.6	-13%--6% -16%--4%	2050	Strzepek and McCluskey (2007)

Region	Model	Scenario	Temperature	Rainfall	Year	Reference
	HadCM3, ECHam4	A2 B2	+5.4-8.7 +3.8-6.3	-34%--15% -29%--9%	2100	

Table 1.5.3: Variability in temperature and rainfall in Malawi predicted by different climate models under different climate scenarios

Region	Model	Scenario	Temperature	Rainfall	Year	Reference
Malawi	15 models	A2 A1B B1	+1.1-+3.0°C +1.5-+5.0°C	-13%-+32%	2060 2090	McSweeney et al. (2010)
Malawi	ECHAM4/OPY C3 HadCM3 CSIRO-Mk2 CGCM2 GFDL-R30 CCSR/NIES	A2	+3.9°C	-1.9%	2070-99	Cline (2007)
Malawi	HADCM2 CSIRO-TR ECHAM2 CGCM1-TR		+1°C -+3.0C	-16%-+22%	2100	MNREA (2002)

Table 1.5.4: Variability in temperature and rainfall in Mozambique predicted by different climate models under different climate scenarios

Region	Model	Scenario	Temperature	Rainfall	Year	Reference
Mozambique	15 models	A2 A1B B1	+0.5-+1.7°C	-13%-+7%	2030	McSweeney et al. (2010)
			+1.0-+2.8°C	-13%-+13%	2060	
			+1.4-+4.6°C	-15%-+34%	2090	
Mozambique	ECHAM4/OPYC3 HadCM3 CSIRO-Mk2 CGCM2 GFDL-R30 CCSR/NIES	A2	+3.84°C	-0.7%	2070-99	Cline (2007)
Mozambique	UKMO	2×CO2	+2.8°C	-9%	2075	MICOA (2003)
	Genesis		+1.8°C	-2%		
	GFDL R30		+3.1°C	-11%		
	UK89		+3.1°C	-9%		
Pungwe Basin	ECHAM4	A2	+1.5-+2.2°C	-5%-+5% in Dec-May -10%--20% in Jun-Nov	2050	Anderson et al. (2011)
		B2				
	CCSM3	B2				

Table 1.5.5: Variability in temperature and rainfall in Rwanda predicted by different climate models under different climate scenarios

Region	Model	Scenario	Temperature	Rainfall	Year	Reference
Rwanda	19 models	B1	+0.7 (0.4 to 1.1)	3 (-1 to +15)	2020	ROR (2011)
			+1.4 (0.9 to 1.9)	5 (-4 to +15)	2050	
			+1.9 (1.4 to 2.7)	5 (-5 to +18)	2080	
		A1B	+0.9 (0.4 to 1.1)	4 (-4 to +10)	2020	
			+1.9 (1.2 to 2.4)	6 (-4 to +18)	2050	
			+2.9 (2.0 to 3.8)	7 (-4 to +31)	2080	
		A2	+0.9 (0.5 to 1.0)	0 (-2 to +7)	2020	
			+1.8 (1.3 to 2.2)	3 (-6 to +17)	2050	
			+3.2 (2.5 to 3.8)	7 (-5 to +29)	2080	
Rwanda	PCM_00	1CO_2	+0.44	Increase in dry season	2020	MNR (2012)
			+1.3		2050	
			+2.5		2100	
	IAP_97		+0.5	Increase in rainy season, decrease in dry season	2020	
			+1.3		2050	
			+2.3		2100	
	LMD_98		+0.6	Increase in rainy season, decrease in dry season	2020	
			+1.9		2050	
			+3.3		2100	

Table 1.5.6: Variability in temperature and rainfall in Tanzania predicted by different climate models under different climate scenarios

Region	Model	Scenario	Temperature	Rainfall	Year	Reference
Tanzania		2×CO_2	+3°C -5°C (daily) +2°C -4°C (annual)	+5%-45% (bimodal rainfall areas) -5%-15% (unimodal rainfall areas)	2075	URT (2003)
Tanzania	11 GCMs	B2	+1.3°C	+5.9%	2050	Agrawala (2003)
			+2.2°C	+10.2%	2100	
Tanzania	Ncar_ccsm3_0	A1B	+1.9°C	+5.7%	2041-2050	Arndt et al. (2012)
	Ncar_pcm1	A1B	+1.1°C	+5.4%		
	Csiro_mk3_0	A2	+1.4°C	+13.3%		
	Ukmo_hadgem1	A1B	+1.5°C	-11.1%		
Tanzania	ECHAM4/OPYC3 HadCM3 CSIRO-Mk2 CGCM2 GFDL-R30 CCSR/NIES	A2	+3.19°C	-7%	2070-99	Cline (2007)

Table 1.5.7: Variability in temperature and rainfall in Uganda predicted by different climate models under different climate scenarios

Region	Model	Scenario	Temperature	Rainfall	Year	Reference
Sezibwa Catchment	AIM	A1B	DJF: +2.41°C MAM: +2.38°C JJA: +2.76°C SON: +1.78°C	DJF: +31.9% MAM: +19.0% JJA: +14.3% SON: +13.0%	2070-2100	Abaho et al. (2011)
	ASF	A2				
	MES	B2				
	IMA	B1				
Lira and Entebbe	CCCM GFDs UK 89	Doubling CO_2	+2.31-+3.48°C	-2.4%-+17%	2100	ROU (2002)
Uganda	ECHAM4/OPYC3 HadCM3 CSIRO-Mk2 CGCM2 GFDL-R30 CCSR/NIES	A2	+3.7°C	+1.9%	2070-99	Cline (2007)
Ssezibwa Catchment	HadCM3	A2 B2	+1-+3°C	>+30% >+80% >100%	2020s 2050s 2080s	Nyenje and Batelaan (2009)
Uganda	15 models	a2 a1b b1	+0.5-+1.7°C	-7%-+11%	2030	McSweeney et al. (2010)
			+1.0-+3.1°C	-5%-+25%	2060	
			+1.4-+4.9°C	-9%-+46%	2090	

Table 1.5.8: Variability in temperature and rainfall in Zambia predicted by different climate models under different climate scenarios

Region	Model	Scenario	Temperature	Rainfall	Year	Reference
Zambia	15 models	A2 A1B B1	+0.6-+1.8°C	-9%-+10%	2030	McSweeney et al. (2010)
			+1.2-+3.4°C	-10%-+6%	2060	
			+1.6-+5.5°C	-8%-+13%	2090	
Zambia	ECHAM4/OPYC3 HadCM3 CSIRO-Mk2 CGCM2 GFDL-R30 CCSR/NIES	A2	+4.3°C	-5.1%	2070-99	Cline (2007)
Zambia	HadCM3	-	+2°C	Marginal increase in region I and II Moderate increase in region II Significant increase in region III	2070	MTENR (2007)
Zambia	PCM, CGCM2, CSIRO2, HadCM3, ECHam4	A2 B2	+2.2-4.1 +2.2-4.2	-5%-+5% -6%-+2%	2050	Strzepek and McCluskey (2007)
		A2 B2	+5.4-10.0 +3.8-7.3	-13%-+12% -10%-+4%	2100	

Table 1.5.9: Effect of climate change on runoff in rivers, basins and catchments

Catchment	Country	Scenario	Model	Change in annual runoff	Year	Reference
Abash River Basin	Ethiopia	Doubling CO_2	CCCM	-33%	2075	Hailemariam, 1999
			GFD3	-10%		
		Temp:+2 Precp:+0%		-9%		
		Temp:+2 Precp:-20%		-41%		
Lake Tana Sub-basin	Ethiopia	Doubling CO_2	CCCM	-18.2%	2075	Tarekegn, D., and A. Tadege, 2006
			GFD3	-12.6%		
			UK89	+2.5%		
		Temp:+2 Precp:+0%		-11.3%		
		Temp:+2 Precp:+20%		-44.6%		
Upper Nile River basin	Ethiopia	A2	Six GSM models	-25% to +32%	2050	Kim and Kaluarachchi, 2009
River Pangani/Ruvu	Tanzania	Doubling CO_2	CCCM	-6 to -10%	Not specified	URT, 2003
River Rufiji				+5 to +11%		
Mara River basin	Kenya	Temp:+1.8 Precp:-3%		-25%	2099	Mango et al., 2011
		Temp:+1.8 Precp:+7%		+3%		
		Temp:+4.3 Precp:+25%		+36%		
Nzoia Catchment	Kenya	A2	CCSR CSIRO ECHAM4 GFDL HADCM3	+38% to +56%	2020	Githui, 2008
		B2		+6% to +20%		
		A2		+65% to +115%	2050	
		B2		+11% to +42%		
Sezibwa River catchment	Uganda	A2	HADCM3	+38%	2010-39	Nyenje and Batelaan, 2009
				+60%	2040-69	
				+125%	2070-99	
		B2		+24%	2010-39	

Catchment	Country	Scenario	Model	Change in annual runoff	Year	Reference
				+49%	2040-69	
				+88%	2070-99	
Sezibwa River catchment	Uganda	A1B, A2, B2, B1	MAGICC/SCENGEN	+47%	2070-2100	Abaho et al., 2011

1.5.2 Potential adaptation measures

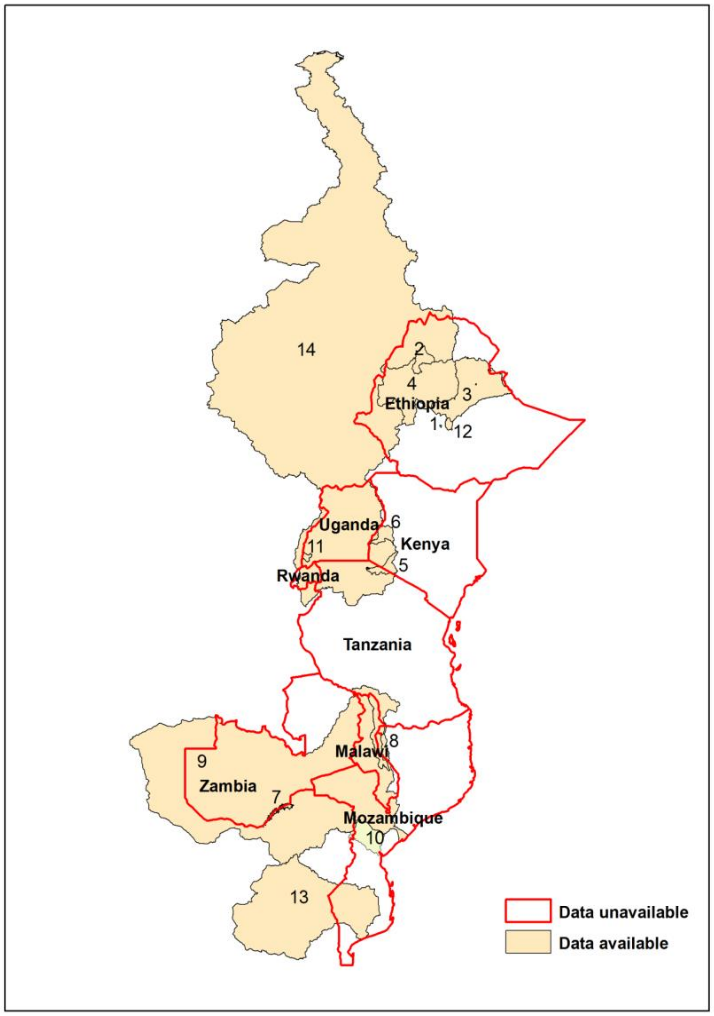
One-third of the people in Africa live in drought-prone areas (World Water Forum, 2000). Projected climate changes will impact agricultural production systems in the region, as more than 95% of farm land in Africa is rainfed and lacks irrigation infrastructure (Wani et al, 2009; Burney and Nayler, 2012). Switching to more drought tolerant crops and adoption of drought tolerant varieties will help to offset climate change impact to some extent. Soil and water conservation measures will also help retain soil moisture and retain nutrients. However, irrigation is the primary adaptation measure immediately available that can be deployed to cope with rainfall anomalies. In the region, a lack of irrigation facilities has limited cropping intensity, leaving the lands fallow during dry seasons (Thurlow et al., 2012). Cereal grain-yield more than doubles when produced under irrigation rather than relying on precipitation (Rosegrant et al., 2002). Small-scale irrigation facilities could increase production and reduce vulnerability as it offers the expansion of agriculture into drier-ecological zones (Muhanji et al., 2011).

Most of the large-scale irrigation schemes in sub-Saharan Africa have proven to be expensive and environmentally unsustainable (Ngigi, 2003). Frequently, high capital investment and poor performance of major irrigation projects are cited as the reasons for under-development of irrigation infrastructure (Fujiie et al., 2011). Construction of economically viable large-scale irrigation in sub-Saharan Africa is inhibited by natural and social conditions and, thus, the prospect of the development of major formal irrigation schemes in the region is dim (Fujiie et al., 2011). In contrast, small-scale irrigation systems require less effort and resources for construction, operation, and maintenance, and offer more flexibility than conventional large-scale irrigation schemes that require large initial investments and public associations (Burney and Nayler, 2012).

1.5.3 Major constraints

One of the major constraints in predicting the effects of climate change on water resources is the lack of readily available regional or statistical climate data or modeled products to conduct inter-comparison studies (see section 1.4). Researchers often use low resolution GCM output as an input to model the impact of climate change on water resources (UNECA, 2011). More reliable regional models would present a clearer picture of the impacts of climate change on the water resources in the region. Some reports suggest that in some parts of the region, farmers solely blame deforestation for rainfall variation, while other farmers elsewhere consider climate change as the sole factor in crop yield reduction (Hepworth, 2010; Mongi et al., 2010). Adequate knowledge on climate change and its implications will be a key factor in building resilience to climate change. Due to high poverty levels in the region, lack of capital investment is another major challenge in implementing adaptation measures. This constraint is also highlighted in National Adaptation Programmes of Action (NAPA) developed by all the Feed the Future nations in the region. Climate change associated rainfall variability and evapotranspiration will impact river runoff and information on the level of impact will be crucial for existing and future irrigation schemes. However, as can be seen from Figure 1.5.1, climate change impacts have not been studied for a large part of the region. Currently, the impacts of climate change on water resources are not explicitly taken into account in most of the African water sector policies

(UNECA, 2011). A coordinated policy level approach that involves all the stakeholders would be required to formulate and implement the adaptation measures to ensure water availability in the future.



Number	Catchment/Basin
1	Lake Abiyata
2	Gilgel Abay
3	Abash
4	Upper Nile
5	Mara
6	Nzoia
7	Lake Kariba
8	Lake Malawi
9	Zambezi
10	Pungwe
11	River Mitano
12	Ketar
13	Limpopo
14	Nile

Figure 1.5.1. Areas previously studied for the impacts of climate change on water resources

Intractable and well-known problems

- Water resources availability
  - Increased population has increased pressure on water resources.
  - All the countries, except Mozambique and Zambia, are either water stressed or close to it.
- Water storage capacity
  - Water storage capacity is low in the region.

- Limited water is available for irrigation during dry season.

- Reliance on rainfall
  - Irrigation development is very low.
  - Crop productivity depends on rainfall variability.

Intractable but lesser-known problems

- Availability of water and possibility of irrigation
  - In some places, water can only be utilized for irrigation through pumping.
  - Energy requirement and associated pumping cost are one of the major constraints in irrigation development (ADF, 2006).
- Intra-season rainfall variability and water availability
  - Short-term dry spells during reproductive growth stage reduces crop yield substantially (MNREE, 2011).

Novel ideas that might be actionable

- Drilling new boreholes, deepening existing boreholes and repairing damaged boreholes (Elliot et al., 2011)
- Installing shallow wells and hand-dug wells for smallholders to supplement the shortfall of water, especially during the dry season (Ngigi, 2009)
- Rainwater harvesting from ground surface and rooftops (Elliot et al., 2011)
- Capacity building for small scale irrigation planning

1.5.4 Summary

Climate change and population increase are likely to increase pressure on water resources in East Africa. Annual and seasonal variability in rainfall will impact crop production systems as most agriculture in the region is rainfed. Increasing temperature will further increase moisture stress by elevating evapotranspiration rates. Adoption of heat resistance and drought tolerant crops, development and dissemination of drought tolerant varieties, and supplementing rainfall through the development of small-scale irrigation schemes would help farmers build resilience to climate change. In the context of population pressure and climate change, a coordinated policy level approach by the governments is needed to address the water resource issues.

1.6 Pressures on Land

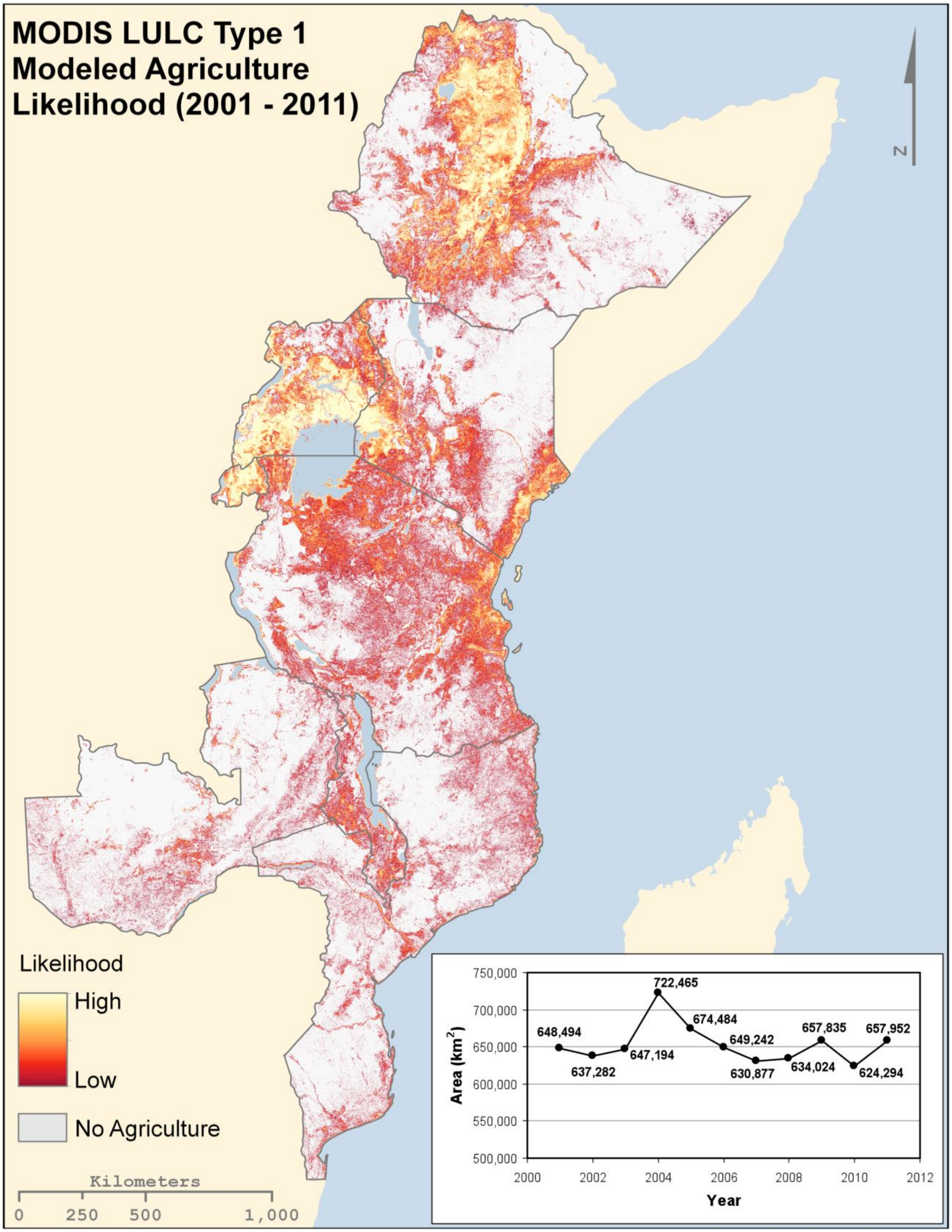
The scale, spatial extent, and magnitude of anthropogenic changes of the land surface in East Africa are profoundly altering the ability of the local populations to adapt to the largely exogenous driver of climate change. Climate change exerts considerable pressure on agricultural systems in numerous ways including shifts in the duration and timing of growing seasons, crop suitability, amount of arable land available for cultivation or grazing, and both the quantity and quality of food production. In East Africa, where land pressure is already considered high (Fermont et al., 2008), there is general consensus that the impacts of climate change on agriculture will add significantly to development challenges ensuring food security and reducing poverty (Thornton et al., 2009). Given that the Eastern and Southern African regions exhibit considerable spatial and temporal variability in both climate and physical geography, the responses of different crops to climate change should be anticipated (Thornton et al., 2010). Better understanding of the thresholds associated with East African food systems is critical (Thornton et al., 2011).

1.6.1 Data

Currently, the changes in land use and land covers over most of East Africa are poorly documented. The best digital product (Africover) is almost 20 years old. The more modern automated satellite products like MODIS Landcover, while an important scientific resource, contain substantial uncertainty, and largely underestimate agricultural lands. Another recent land cover product, Globcover, overestimates forest and woodland classes (Tanzania) (Swetnam et al., 2010). Agricultural extensification has emerged most frequently on lands converted from traditional savannah shrublands (Gibbs et al., 2010). This expansion of cultivation in many parts of East Africa has significantly altered land covers and reduced natural vegetation far in excess of net additional food production. These changes are fueled by growing demand for agricultural products necessary to improve food security and generate income not only for the rural poor but also for the large-scale investors in the commercial farming sector. Food production in Kenya, for example, is reported to have increased steadily, but because of concomitant population increases, the food supply in calories per head fell slightly during that same period (Maitima et al., 2009). Further, after land cover conversion from natural vegetation to cultivation or grazing, land uses become constrained due to local intensification and diversification as land becomes less available and farm sizes become smaller through subdivision (Maitima et al., 2009).

Modern remote sensing technology allows the efficient gathering of information on, and mapping of, LULC on the earth's surface (Congalton and Green, 2008), especially in difficult to access regions. However, none of the existing LULC data sets available for East Africa are truly adequate to account for change in agricultural systems within the region. Eleven public LULC products are available for East Africa (Table 1.6.1) from sources including National Aeronautics and Space Administration (NASA), European Space Agency (ESA), International Geosphere-Biosphere Programme (IGBP), the Food and Agriculture Organization of the United Nations (FAO), The Global Environment Monitoring Unit at the University of Maryland (UMd), and the Climate Land Interaction Project (CLIP) located within the Center for Global Change and Earth Observations at Michigan State University. Each LULC data set is unique based on production methods, classification scheme, temporal acquisition date, and intended use. Despite the wealth of data offered by each LULC data set, without exception, each data set suffers from either high levels of uncertainty, a lack of LULC class specificity, or covers a limited temporal scale making it inadequate for agricultural change research.

High levels of uncertainty within a LULC data set, in particular possible misclassification of agriculture, results in unusable information (Figure 1.6.1). LULC products with a generalized agricultural class lack the specificity to distinguish between important regional agricultural crops, allowing the user to infer only general trends. Particular crops, such as maize or sorghum, are indistinguishable despite requiring different environmental conditions (ecological niches) for cultivation and substantially different land and social pressure. Conversely, if a data set has both low uncertainty and necessary class specificity but has a limited temporal scale (e.g., was only produced for one year), then no change detection is possible. Ideally, a data set used for agricultural research should contain low uncertainty, agriculture class specificity, and repeating temporal coverage.



MODIS LULC Type 1
Modeled Agriculture
Likelihood (2001 - 2011)
N
Likelihood
High
Low
No Agriculture
Kilometers
0
250
500
1,000
750,000
700,000
650,000
600,000
550,000
500,000
Area (km2)
648,494
637,282
647,194
722,465
674,484
649,242
630,877
634,024
657,835
624,294
657,952
2000
2002
2004
2006
2008
2010
2012
Year

Figure 1.6.1

The IGBP DISCover land cover product produced by the United States Geological Survey (USGS) Land Cover Working Group in 1995 was created using the Advanced Very High Resolution Radiometer (AVHRR) Normalized Difference Vegetation Index (NDVI) 10-day composites from April 1992 to May 1993 (Hansen & Reed, 2000). The land cover classes were determined using unsupervised classification on the AVHRR NDVI data on a continental scale and resulted in a Cropland and Cropland/Natural Vegetation Mosaic LULC class (Loveland et al., 2000). The accuracy of the IGBP DISCover land cover product has been estimated at 66.9% for overall area-weighted accuracy, and a cropland user accuracy of 64% (Scepan, 1999). The Global Land Cover Facility at the UMd produced the UMd Global Land Cover Classification (GLCC) LULC data set utilizing the same underlying remotely sensed AVHRR NDVI data as the IGBP DISCover land cover product but employed a decision tree classification method resulting in a different classification scheme (Hansen et al., 2000). As explained in Hansen and Reed (2000), the major difference between the IGBP DISCover and the UMd GLCC classification schemes is the exclusion of several LULC classes, including the cropland / natural vegetation mosaic class, resulting in a single agriculture class. No formal accuracy assessment has been performed on the UMd GLCC product, though the reported agreement between the UMd GLCC product and the IGBP DISCover is 74% (Hansen and Reed, 2000).

The Global Land Cover 2000 (GLC2000) product was produced by the Joint Research Centre Global Vegetation Monitoring Unit and using a 14 month (November, 1999 to December, 2000) of *VEGETATION* imagery from the SPOT-4 satellite (Torbick et al., 2006). The classification scheme used by GLC2000 was the Land Cover Classification System (LCCS) designed by the FAO, which produced a 26-class Africa specific data set with 2 Cropland classes (Di Gregorio & Jansen, 2000). Mayaux et al., (2006) have estimated that the overall global accuracy of the GLC2000 data set is 68.5 ± 5 %.

GlobCover was produced by ESA using data from the 300m MERIS sensor on board the ENVISAT satellite mission (Defourny et al., 2006). The classification scheme used by GlobCover was nearly identical to that of the GLC2000 (Bicheron et al., 2008) with only 2 Cropland classes and possible overestimation of forest and woodland classes (see Swetnam et al., 2011). Two data sets are available; the first has a temporal range of December 2004 to June 2006 with an overall accuracy of 67.1% (Bicheron et al., 2008), and the second was from January to December 2009 with an overall accuracy of 58.0% (Bontemps et al., 2011).

Five types of Moderate Resolution Imaging Spectroradiometer (MODIS) Global Land Cover products have been produced. The MODIS Global Land Cover products were produced annually from 2001 to 2011 with a spatial resolution of 500m. The MODIS Type 1 product is produced using MODIS NDVI data and the same IGBP global vegetation classification scheme as the IGBP DISCover land cover product, with a cropland and natural vegetation mosaic classes (Friedl et al., 2002). MODIS Type 2 uses the UMd modified IGBP scheme and methodology and the same MODIS NDVI data used to create the MODIS Type 1 land cover product, with a single cropland class (Zhan et al., 1999). The MODIS Type 3 land cover product is derived from known relationships between estimated leaf area index (LAI) and fraction of photosynthetically active radiation (FPAR), with grass / cereal crop and broadleaf crop classes (Tian et al., 2000). The MODIS Type 4 land cover product is derived from the net primary production (NPP) MODIS products, which measure the growth of the terrestrial vegetation. The MODIS Type 4 classification scheme is primarily geared towards the identification of forest types, such as deciduous broadleaf vegetation and evergreen broadleaf vegetation, and contains no agriculture class. The MODIS Type 5 land cover product was designed to be used in the Community Land Model for the purposes of climate modeling, focuses on classifying land cover type based on the plant functional type or plant biome, and contains both grass / cereal crop and broadleaf crop classes.

The Africover LULC data was created by combining both computer-based unsupervised classification and an expert system supervised classification performed by visual interpretation of mid-1990s era Landsat images by local experts (Torbick et al., 2006). Several country specific Africover products exist; however, these country specific data sets were spatially aggregated to create generalized data sets that could be compared among countries. The original country-specific Africover products are in vector format, with varying number LULC classes, and generally have a nominal scale of 1:200,000. The final LULC data set discussed here is CLIP Cover produced by the CLIP project at Michigan State University. The CLIP Cover LULC product is a hybrid of GLC2000 and Africover land cover products and uses Africover agricultural data where available and GLC2000 non-agricultural land cover data (Torbick et al., 2006). Of the eleven currently available (publically) LULC data sets, only two, Africover and CLIP Cover, contain enough agricultural class specificity to be useful in agricultural research. However, CLIP Cover is a hybrid product that uses the Africover agricultural data; thus, they essentially provide the same information to the user. While Africover contains better class specificity, it was only produced once, in the late 1990s, and thus does not effectively allow for LULC change detection research. Conversely, the IGBP DISCover, GLC2000, and MODIS type 1 LULC data sets allow for change detection research, but the highly generalized agriculture classes do not provide the necessary level of detail to perform meaningful agricultural change research. In addition to being highly generalized, comparing Africover agricultural classes to the MODIS type 1 agricultural classes one can see clear areas of disagreement (Figure 1.6.2), drawing into question the overall accuracy and usefulness of the MODIS data sets for these applications.

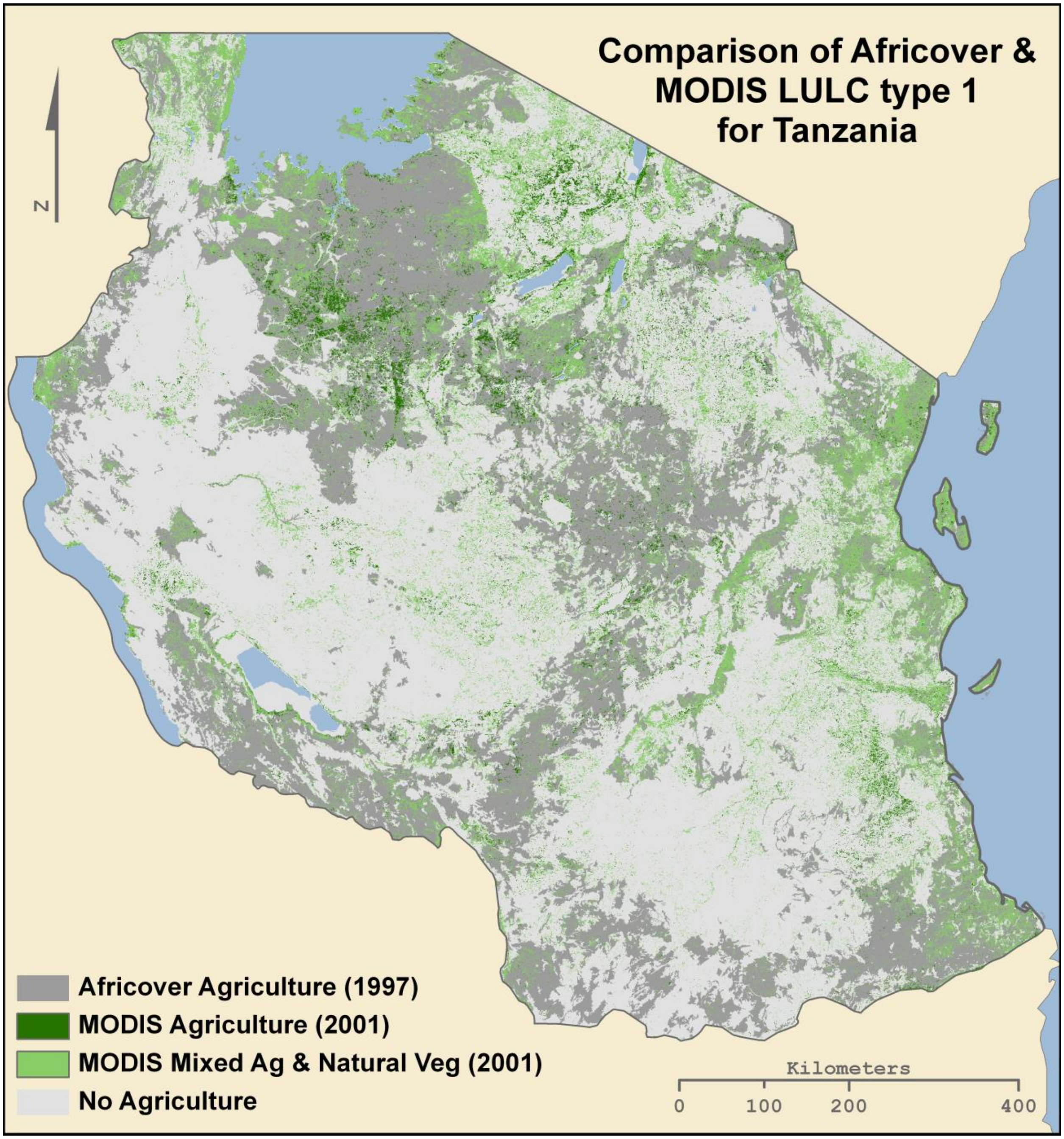

Comparison of Africover & MODIS LULC type 1 for Tanzania
N
Africover Agriculture (1997)
MODIS Agriculture (2001)
MODIS Mixed Ag & Natural Veg (2001)
No Agriculture
Kilometers
0
100
200
400

Figure 1.6.2.

Table 1.6.1.

Data Set	Resolution	Classification Scheme	Temporal Range	Platform
Africover	1:200,000	Regional FAO LCCS	1995	LANDSAT
CLIPcover	1km	Combination of GLC2000 and Africover	1995 / 1999 – 2000	NA
GLC2000	1km	FAO LCCS	1999 – 2000	SPOT 4
IGBP DISCover	1km	IGBP	1992 – 1993	NOAA
UMd GLCC	1km	UMd modified IGBP	1992 – 1993	NOAA
GlobCover	300m	GlobCover	Dec 2004 - June 2006 and Jan - Dec 2009	ENVISAT
MODIS Type 1	500m	IGBP	Produced Annually 2001 – 2011	MODIS Terra & Aqua
MODIS Type 2	500m	UMd modified IGBP	Produced Annually 2001 – 2011	MODIS Terra & Aqua
MODIS Type 3	500m	LAI / FPAR	Produced Annually 2001 – 2011	MODIS Terra & Aqua
MODIS Type 4	500m	Net Primary Production	Produced Annually 2001 – 2011	MODIS Terra & Aqua
MODIS Type 5	500m	Plant Functional Type	Produced Annually 2001 - 2011	MODIS Terra & Aqua

1.6.2. Patterns and Process

Once multiple years of accurate agricultural specific LULC data are available, numerous well-established methods and software exist capable of analyzing LULCC. Preliminary analysis should focus on examining the patterns of LULCC on the landscape, with particular attention given to change involving food production systems. Good LULCC detection research should provide information on following: (1) quantify rates of change; (2) spatial distribution of change; (3) trajectories of LULCC; and (4) change detection accuracy assessment (Lu et al., 2004). In addition, the patterns of LULCC can vary over time, so to aid in accurately distinguishing between linear, first or second order, and accelerating / decelerating LULCC, it is necessary to obtain data spanning the longest temporal period possible (Dearing et al., 2010).

Subsequent research should move beyond characterizing spatial patterns and focus on studying the processes that drive change (Bürgi et al., 2004). Drivers of LULCC can be complex and convoluted, commonly involving a combination of natural processes and human activity (Loveland et al., 1999). Thus, accurate ancillary data spanning a broad array of social and biophysical domains and at various spatial scales is often necessary to identify processes driving LULCC (Messina et al., 2008). The importance of scale cannot be stressed enough and must be addressed in all LULCC analysis, as the results can vary along the spatial scale continuum (Manson, 2007).

1.6.3. Modeling LULCC

After the patterns and processes surrounding agricultural LULCC are understood, research should focus on analyzing the impact of process perturbations on food production systems. Due to the convoluted dynamics involved in human and environmental systems, such analysis is commonly performed within a computer simulation environment, often in the form of complex LULCC models (Turner et al., 2007). Many LULCC modeling frameworks have been developed (e.g., process based, cellular automata, and agent-based models), with many of them undergoing continuous evolution towards increasing complexity (Sohl and Claggett, 2013). While choosing an appropriate LULCC modeling framework is highly dependant on the framework's capacity to accurately represent the system of interest, spatially explicit LULCC models should be favored over those that are aspatial.

The emphasis on using spatially explicit models is threefold: 1) spatially explicit models offer the ability to not only explore the sensitivity of food production systems to variables driving change but also allow for the exploration of scale dependency, stationarity, both positive and negative feedbacks, and possible future real-world conditions (Veldkamp and Lambin, 2001), 2) spatial explicitness produces regionally specific estimates that are determined by that region's unique characteristics as well as its interconnectedness with other regions (Crowther and Haimes, 2010), and 3) the convenience of translating spatially explicit model outputs and results into information more readily usable by policy makers, natural-resource management officials, and various other stakeholders (Evans et al., 2006; Agarwal et al., 2007).

Despite the chosen modeling framework's ability to theoretically represent the system of interest accurately, it is important for the researcher to recognize that perfectly predicting LULCC is impossible (Sohl and Claggett, 2013), especially given the complexity associated with food production systems. Although no model is perfect, some models can be useful (Box, 1976). The usefulness of LULCC modeling is the opportunity it affords the researcher to gain fresh insights into highly complex systems, using various process perturbation scenarios (Walsh et al., 2008).

For example, there is general consensus that the impacts of climate change on agriculture will add significantly to development challenges ensuring food security and reducing poverty (Thornton et al., 2009), and the responses of different crops to climate change should be anticipated (Thornton et al., 2010). A spatially explicit complex LULCC model, parameterized with information obtained from a LULCC analysis performed on accurate agriculturally specific LULC data, and coupled with climate, socioeconomic and population change scenarios, could be useful in identifying populations at risk and exploring the potential mitigating strategies. Similar models could be used to test the potential for change in arable /marginal lands under agricultural innovation, water resource allocation, and population migration / growth scenarios.

1.6.4. Conclusion

Questions surrounding agricultural change are an impediment to improving food production systems. In particular, climate change has the potential to impact the timing of growing seasons, the quality and quantity of foodstuffs, and amount of arable land. While it is routinely possible to address LULCC questions on per-location basis, synoptic analyses of climate and land interactions with generalizable results on food systems is only possible following substantial improvements to existing LULC data or replacement with a targeted product. Subsequent research can then analyze the patterns and processes of LULCC, followed by development of complex coupled LULCC models to explore possible change scenarios.

1.7. Population and Migration

As early as 1990, the Intergovernmental Panel on Climate Change (IPCC) stated that "one of the greatest effects of climate change may be those on human migration" (IOMa, 2013). The scale of climate-induced migration is quite alarming, conservatively estimated at 25 million (IOMa, 2013); future migration estimates range from 250 million (Christian Aid, 2007) to 1 billion (IOMa, 2013) persons by 2050. Some reports also connect climate change to violent conflict that further induces migration; although, a direct causal linkage has been questioned (Samaan, 2011; Theisen et al., 2011/12). There are numerous types of migration linked to global climate change, but it is rural-urban migration that continues to stand out as one of the most significant features of population dynamics in East Africa (Djurfeldt et al, 2013; McGranahan et al, 2009; Potts 2009 & 2012) and may be one of the least understood outcomes of climate change.

Within East Africa, urbanization ratios vary from 11% (Burundi – 2011) to 39% (Zambia – 2011). The region is experiencing faster urban growth than other low-income regions, with annual growth rates varying from 3.6% to 5.9% in 2011 (World Bank, 2013a). In contrast to urbanization in developed or emerging countries where urbanization is driven by economic development, rural-urban migration in Sub-Saharan Africa is primarily driven not by the pull of industrialization in urban areas but due to the push factors of poverty in rural areas (Djurfeldt et al, 2013; Locatelli and Nugent 2009; Nyakaana et al, 2007), including low agricultural production due to decreased rainfall (Barrios et al, 2006). Conversely, rural-urban migration produces remittances that support agricultural production in rural areas, which in turn has land use and cover consequences (Greiner and Sakdapolrak, 2012).

While the literature has established strong relationships between climate change and rural-urban migration, there remains a need to evaluate causal factors; these relationships are challenging to demonstrate due to inconclusive evidence from past studies, the complexity of the relationships among different factors, and the lack of micro-datasets of different environmental and social conditions (Mendola, 2012; White 2011; Black et al, 2008; Byerlee, 1974; Mabogunje, 1970; Todaro, 1969 & 1971). Difficulties in predicting the impacts of climate change on population movements can also be attributed to the high level of uncertainty and unpredictability about the local effects of climate change, and the lack of comprehensive data on urbanization and migration flows (Tacoli, 2009; Djurfeldt et al, 2013). This is particularly true for marginalized urban migrants, who may actively hide their presence in urban centers in order to avoid harassment and violence (Grace, 2013; Sommers, 2001). Nevertheless, the literature has sufficiently demonstrated that the impacts of climate change on population dynamics are mediated by vulnerability, resilience, and resources of the affected individuals, communities, regions, and nation-states (Hugo, 2012).

It is vulnerable people, especially those disadvantaged by income, gender, race/ethnicity, and other marginalized statuses in the climate hot spots of the Global South that are most adversely affected by climate change (Resurreccion and Sajor, 2012). Further, while women are particularly vulnerable to gender-based discrimination and marginalization within patriarchal kin relations, their capacity to reconfigure their marginalization in adaptive ways is just beginning to be studied

(Gabrielsson and Ramasar, 2012; Resurreccior and Sajor, 2012). We, therefore, seek innovative solutions, including policies, mechanisms and organizations, to address the empowerment of migrants, the equitability of migration, and forced resettlements in climate hot spots of East Africa.

1.7.1. Trends in Population Dynamics and Implications for Farming Systems in East Africa

Increasing population and concomitant consumption are important drivers of the rising demand for food and natural resources across the globe, and especially in developing countries. This is leading to much speculation over how we will be able to feed everyone by 2050, as seen in the Economist magazine's special report titled, "The 9 billion-people question: A special report on feeding the world" (Economist, 2011). Impacts on the environment, including greenhouse gases, are also unknown. Africa, in particular, faces the critical challenge of its population continuing to grow at a rapid rate while natural resources, especially water and arable land as described earlier, are becoming increasingly scarce and contested. Food is mostly produced by small-scale farmers who may not have the resources, or be in an enabling economic and policy environment, to close the "yield gap" between current and potential yields. To date, most of the increase in food needs of the rising population in Africa has been met by expanding agriculture into new land, but this is becoming less of an option (Foley et al., 2011).

Meanwhile, Africa's population is expected to double in the next 40 years (Figure 1.7.1). Not only do these rising population numbers challenge the ability of countries to provide food security but also challenge them to provide ever increasing number of educational and employment opportunities for the young population. Although most people in East Africa are still living in rural areas where agriculture is the dominant livelihood, this is changing rapidly as economies grow and as people seek non-farm sources of income locally and in urban areas. This has important implications for future food production and consumption patterns.

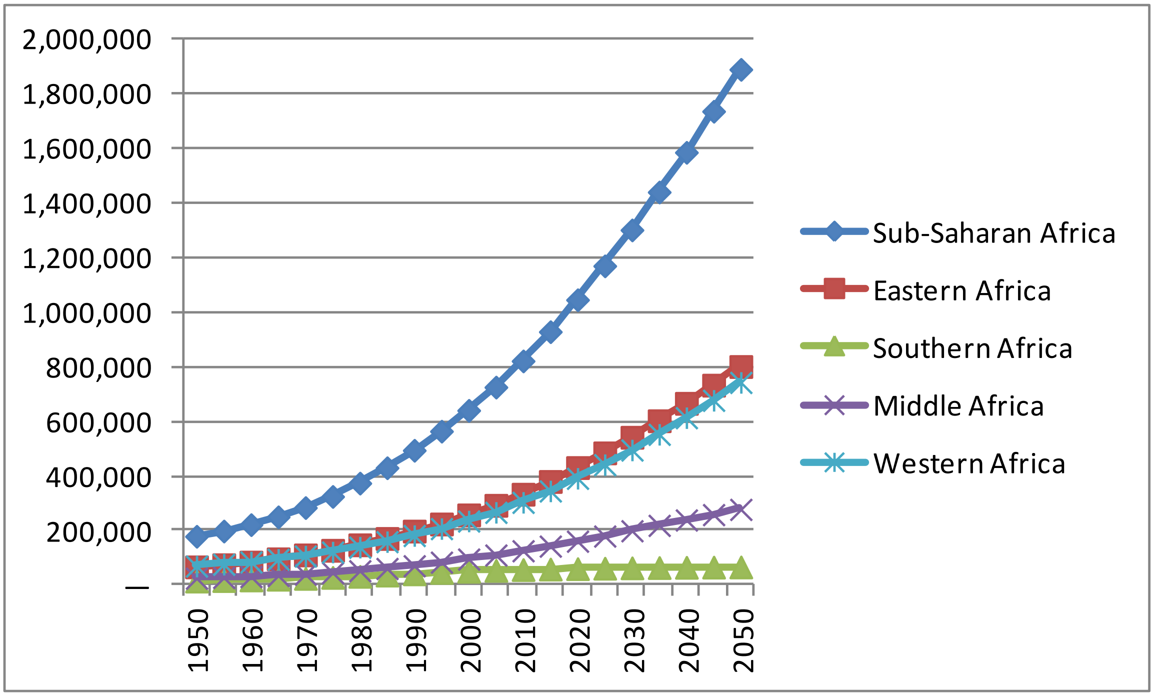


Figure 1.7.1.a. African regional population projections (in thousands). Data source: U.N. 2012.

Meeting the food security needs of the rising numbers of people requires careful consideration of the current trends in population and how they are expected to change. Population in East Africa is dynamic with relatively rapid changes in birth and death rates and in migration patterns. This dynamism reflects the rapidity of change in socio-economic and political factors but is occurring against a backdrop of limited natural resources and relatively few non-agricultural economic opportunities. Climate change and variability is an additional stressor on rural populations threatening to reduce food production. Climate change and extremes, especially drought, have already led to out-migration and landlessness in areas that are under economic or political duress. Projected future climate changes indicate that some areas in East Africa will become less productive for crops, and population shifts are expected.

A key implication for farming systems and for food security of this dynamism in the population is the altered distribution and density of the rural population. Rural-rural migration is leading to new areas being placed under crop production. In many countries, those new areas are increasingly in marginal semi-arid zones that are climatically risky for cropped agriculture. Migration to forest edges is also occurring with implications for deforestation, loss of biodiversity and degradation of watersheds. Much of the rural population growth is, however, continuing to be absorbed locally leading to higher population densities and, where economically supportive, agricultural intensification, or, where not, potentially causing land degradation and worsening poverty.

Out-migration to urban centers is large and complex, with temporary or circular migration by men probably out-numbering the permanent urban migrants in many countries. One result is the large percentage of female-headed households in rural areas, and what has been called a feminization of agriculture (Hazell, 2013). These households tend to have fewer resources, a lower social standing and less social support, and are particularly at risk of any climatic or other shock (Olson et al. 2010).

It is often the most densely populated areas that are the most dynamic and doing the best, which belies concerns over population pressure. Nevertheless, population dynamics are a good reflection wider social and economic trends, and combined with other factors, need to be considered as a critical driver of many changes occurring in East African countries.

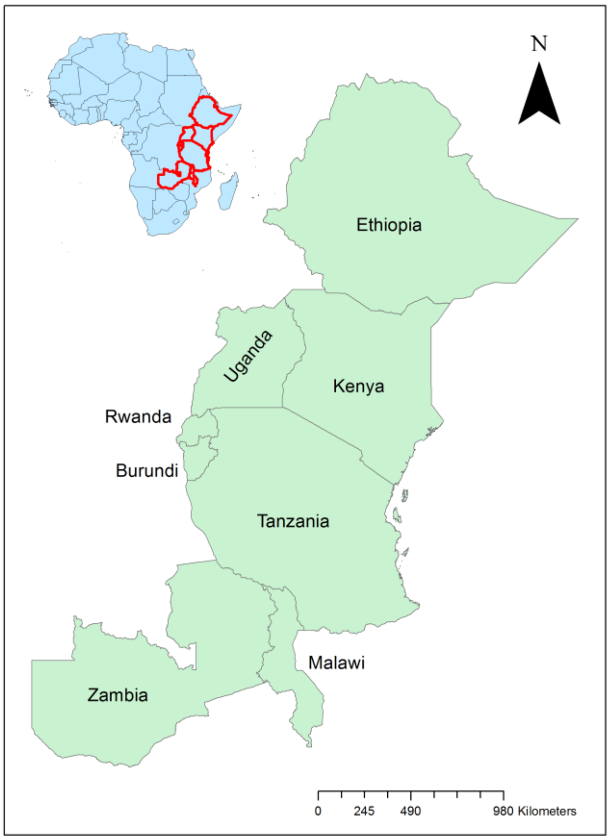


Figure 1.7.1.b. Study Area

This section examines some of the major trends in population dynamics and their implications for farming systems in selected countries in East and Southern Africa (Figure 1.7.1.b.). The components of population change, natural increase and migration, and the interaction between population change and climate change, and their impact on food security are important factors driving migration. Here, we emphasize that population dynamics are a reflection of the wider changes in society but also that research on population dynamics and its links to food security needs to be revived. We argue that climate change adaptation, like economic development, is a socially differentiated process requiring consideration of household and individual gender and wealth characteristics, and consideration of the local economic and environmental context.

1.7.2. Rural Population Distribution

In 2007, 17.5 per cent of the world's rural population lived in Africa. Africa's rural population was projected to increase 29% by 2050 to reach nearly 0.8 billion (UNPD, 2008). Currently, between 75% and 85% of the population in East Africa is dependent on agriculture for their livelihoods (FAO 2013b, USAID 2013).

The spatial distributions of these populations in East Africa are in the process of changing, though the rapidity and direction of change varies. In many areas, people are staying at places of origin, while their society and farming system evolves. The result of population dynamics and other factors is a highly diverse set of farming systems in East Africa, from those that appear stagnant and marginal at best, to others that are developing or adapting rapidly. Maps of population density (Figure 1.7.2) reflect the fact that the rural population tends to be concentrated, especially in highland zones and / or in humid or sub-humid zones where cropped agriculture is productive. Areas of long-standing, historically high population densities and intensive agricultural systems include the Ethiopian Highlands, the Kenyan Highlands, Malawi, Rwanda and Burundi. Other areas, such as in Uganda, Zambia and parts of Tanzania, are also agriculturally productive and have relatively high rural population densities. Close trade and other ties to urban areas has also shaped farming systems and led to relatively high densities, for example around Nairobi, but this phenomena is expected to dramatically increase in the future.

East Africa is, however, characterized by large areas of semi-arid savannas that were previously not developed for cropped agriculture but used by agro-pastoralists or for wildlife conservation. Some of these areas, however, especially those near to farming zones such as in Tanzania and Kenya, have experienced in-migration by farmers coming from the higher-potential zones. The in-migrants, usually along with the original inhabitants, clear the savanna vegetation and attempt to grow rainfed seasonal crops, often maize. The pattern has been one of initial settlement of in-migrant farmers to areas immediately adjacent to their original land, and with time as uncultivated land becomes farther distant, to migrants moving increasingly long distances to seek land (Olson et al. 2004). This pattern occurred, for example, in Kajiado District in southern Kenya as farmers from nearby communities, northern Tanzania and Central Kenya came to cultivate rainfed maize and to drain swamps to grow vegetables. The land under cultivation expanded into the savanna and the former swamps, and permanently changed the local landscape, economy and society (Campbell et al. 2000, Wangui, 2008).

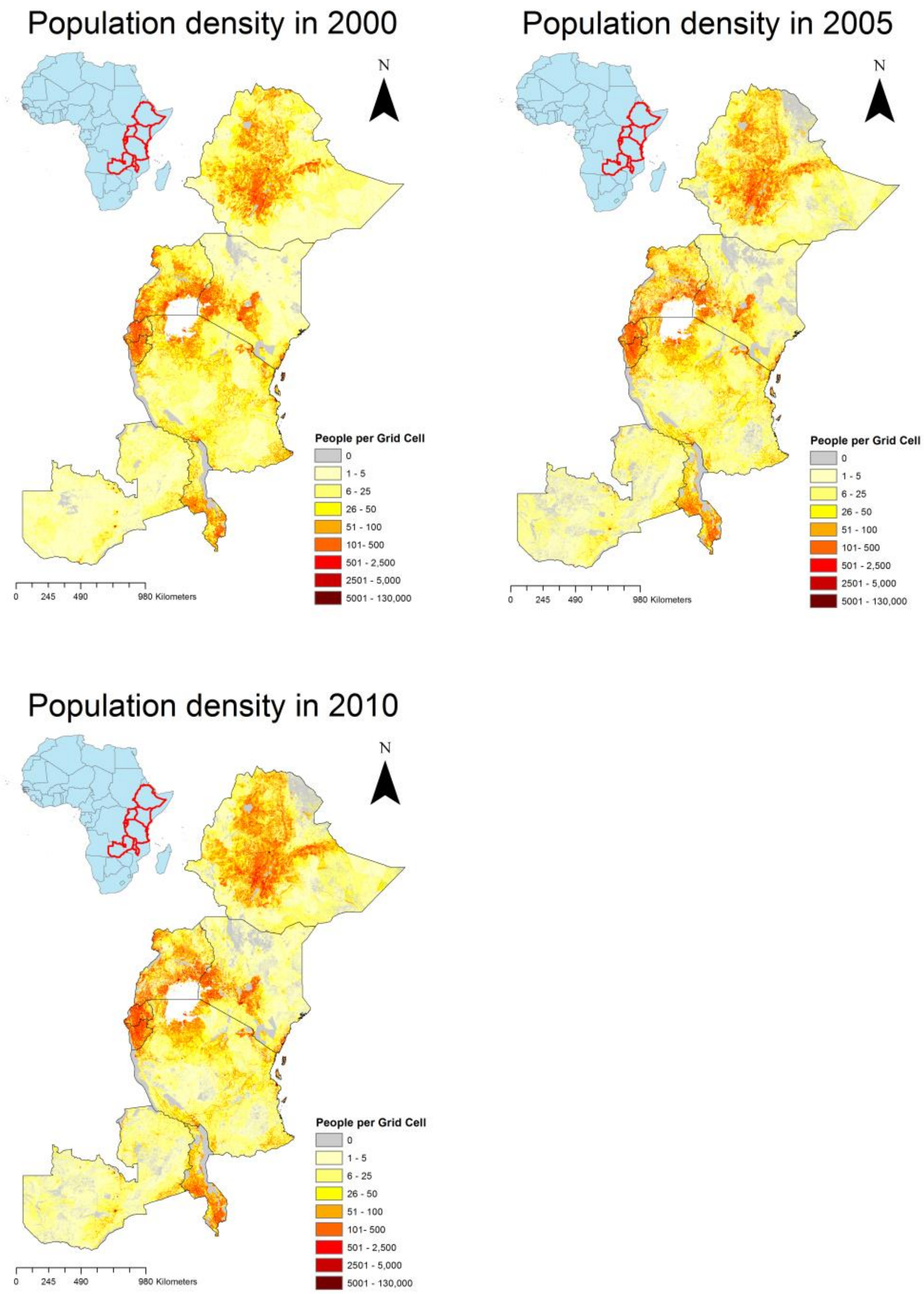


Figure 1.7.2. Population Density in Selected Feed-the-Future Countries, 2000, 2005, and 2010.[2] ..

[2] This map was produced using LandScan (2000, 2005, 2010)™ High Resolution global Population Data Set copyrighted by UT-Battelle, LLC, operator of Oak Ridge National Laboratory under Contract No. DE-AC05-00OR22725 with the United States Department of Energy. The United States Government has certain rights in this data set. Neither UT-BATTELLE, LLC nor the United States Department Of Energy, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of the data set.

The actual population numbers in rural areas and rural population movements in East Africa are difficult to obtain because of inconsistent data collection. Census data made available through IPUMS International do not allow for consistent tracking of rural vs. urban populations over time, as not all measures for these populations are available in every year of data collection. Further, data are collected in different countries in the region in different years, so tracking for the region, as a whole, is not possible without making significant (and possibly false) assumptions. Numerous scholars have noted the insufficiency of available population data as a problem for making accurate projects on climate change impacts, particularly at small geographic scales (Kebede and Nicholls, 2012).

1.7.3. Population Growth due to Natural Increase

1.7.3.a. Changing Birth and Death Rates

Overall the region has experienced rapid population growth: every country except Mozambique and Rwanda doubled its population between 1985 and 2010 (Table 1.7.1.). High fertility rates are the main driver of this growth, with 6.7 children produced per woman for Uganda, 6.2 in Burundi, 5.4 in Tanzania and 4.6 in Kenya and Rwanda (U.N. 2013). The rates of growth vary between countries, however. Annual population growth rates of these countries are as follows: Burundi 2.8%, Ethiopia 2.2%, Kenya 2.6%, Malawi 3.0%, Rwanda 2.9%, Tanzania 2.9%, Uganda 3.2%, and Zambia 2.7% (World Bank 2013).

Table 1.7.1. Total population (thousands, both sexes combined. Data source: U.N.

Country or area	1975	1980	1985	1990	1995	2000	2005	2009	2010	2025	2050
Sub-Saharan Africa	322 292	370 298	426 167	490 115	560 675	638 974	728 004	809 576	831 464		
Burundi	3 677	4 127	4 774	5 606	6 210	6 674	7 770	8 927	9 233	10,791	13,703
Ethiopia	32 570	35 241	40 777	48 043	57 024	66 024	76 167	84 838	87 095	109,989	145,187
Kenya	13 486	16 268	19 660	23 446	27 418	31 285	35 786	39 825	40 909	59,054	96,887
Malawi	5 300	6 237	7 265	9 447	9 964	11 321	12 925	14 573	15 014	24,213	49,716
Mozambique	10 620	12 142	13 339	13 568	15 982	18 276	21 010	23 361	23 967	32,439	44,447
Rwanda	4 359	5 141	6 113	7 215	5 664	8 396	9 429	10 530	10 837	15,684	26,003
Uganda	10 827	12 550	14 661	17 535	20 741	24 276	28 725	32 864	33 987	52,330	94,259
Tanzania	15 978	18 687	21 850	25 485	29 944	34 021	38 824	43 640	44 973	70,879	138,132
Zambia	4 964	5 847	6 838	7 845	8 841	10 101	11 470	12 825	13 217	20,972	45,037

2013

Both birth and death rates have been changing rapidly due to economic and social changes, as considered in the demographic transition model, and due to political or health shocks in the region. The demographic transition describes how societies move from high birth and death rates to low birth and death rates as economic development occurs and as societies change. In Eastern and Southern Africa, this has occurred unevenly over time and between countries. Natural population increase grew dramatically when mortality rates declined starting after WWII due to medial technology (e.g., immunization, antibiotics) when contraception use was still very low (Caldwell and Caldwell, 1987). This decline in mortality rates while birth rates remained high led to the population "boom" reflected in the demographic transition's phase 2. Some countries in East Africa, such as Uganda, are still primarily in this phase.

Subsequently, some countries' governments and some NGOs began to markedly improve access to contraceptives and to promote their use in the 1980s in order to slow the population growth rate to a more manageable level. Governments were having difficulties providing education and employment, and arable land was starting to be seen as a scarce resource in some countries (e.g., Rwanda and Kenya). Figure 1.7.3 illustrates the decline in the total fertility rate (births/woman) in selected countries. Kenya, after having one of the highest population growth rates in the world for many years, was one of the first countries in the region to experience rapidly declining birth rates. Kenya had a relatively aggressive and successful campaign to promote use of contraception. The population growth rate in Kenya went from being one of the highest in the world, close to 4% annually or a doubling every 20 years, to its current rate of 2.6% (Bongaarts 2011, World Bank 2013).

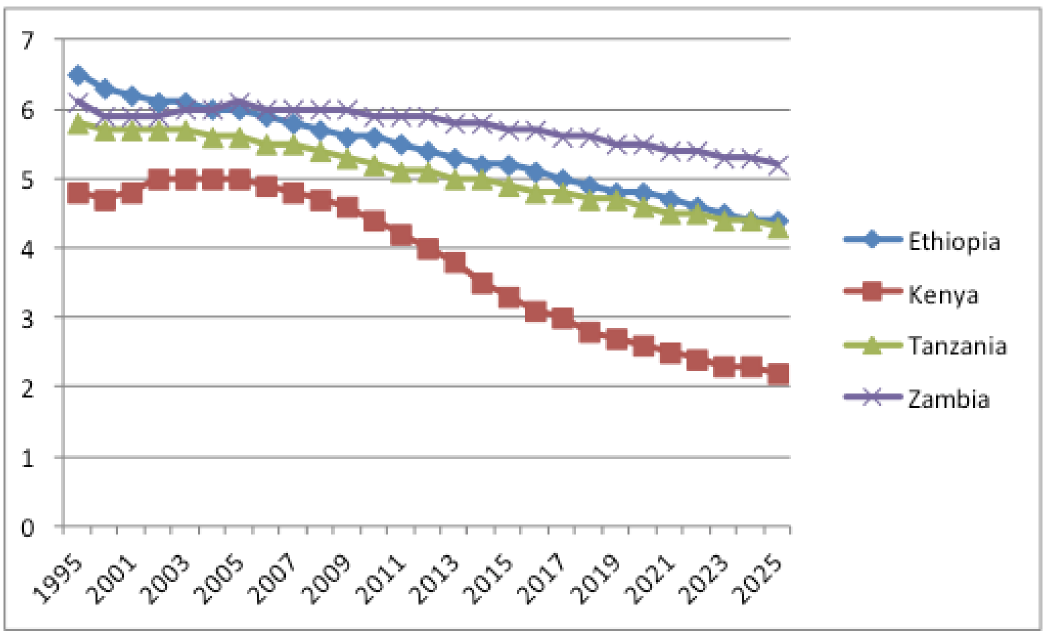


Figure 1.7.3. Total Fertility Rate, 1995 to 2025. Data source: DOC 2013.

Even in rural areas in some countries, birth rates and population growth rates have slowed. Surveys in densely populated Central Kenya indicate that families are finding that children are expensive to rear, with school fees and other expenses, and that families do not have sufficient land to bequeath them. Educating their children, both boys and girls, has thus become a priority for parents (Olson et al. 2003). The Government of Rwanda promoted contraception starting in the 1990s, despite it being a dominantly Catholic country. Several countries have not instituted as aggressive an effort (Cleland, 2009). Nevertheless, contraceptive use has increased as access has grown, partly due to efforts to prevent HIV-AIDS with condoms, and birth rates have fallen in many countries leading to a slowing of the population growth rate. It is still high, however, and populations in the region are expected to continue to grow relatively rapidly.

A large number of East African countries are thus phase 3, the “still rising” phase of the demographic transition, where population growth slows due to a decline of the birth rate, but the birth rate is still higher than the death rate. Typically, as in East Africa, this is associated with rising rates of education, especially among girls, and a shift away from agriculture. The transition theory would then lead us to expect a further reduction in birth rates to eventually equal death rates, and thus a leveling off of the growth rate associated with an aging of the population. No country in East Africa is yet at this fourth phase of the transition.

Some consequences of rapid population growth in East Africa are mentioned above, including the challenges of providing educational and employment opportunities for the large young percentage of the population, and providing sufficient resources including food, energy and fresh water. Another aspect of the projected large population sizes of the countries is the likelihood of a rise in pollution levels including greenhouse gases. Research suggests that reducing the growth of population is one of the most effective ways of mitigating climate change (Wheeler and Hammer, 2010). The rapidity of the growth, combined with increased economic productivity will lead to increased CO_2 emissions and accelerated climate change in East Africa and, indeed, globally well beyond the more optimistic projections (Cleland, 2009).

1.7.3.b. Population Growth and Farming Systems

The link between rural population growth and changes in farming systems has been the source of much research and speculation, with authors writing on the topic starting with Malthus and continuing with Boserup, Tiffen and Mortimore, Grigg, and Gould. With population increases, the value of labor declines relative to land and capital. Some describe how this leads to land degradation and worsening poverty, whereas, others see population growth as a stimulant to increased agricultural productivity.

A cross-site comparison in East Africa showed that the context in which the population growth occurs, however, is critical (Olson et al. 2004). Where the local and national economy permit growth and the selling of higher value commodities, the investment of labor and capital in agriculture can become profitable and successful intensification occurs. The farming system tends towards producing higher value crops and livestock, using more inputs (labor, fertilizer and others), and adopting technology to increase productivity of the land (erosion control, irrigation, zero-grazing cows, etc.). Where the economic context does not promote development, the farming system can stagnate. Population growth can lead to farm fragmentation, landlessness, increased competition for water, fuelwood and other natural resources, and worsening poverty.

Under low or declining rural population density, which is currently rare in East Africa except in semi-arid areas where yields have been declining due to climate change, the farming system would be expected to become more extensive as labor and capital are expensive relative to land. The farming system can evolve towards crops and animals that require relatively less labor and/or capital, a change in inputs used towards those that require low levels of labor, and a change in technology towards that which increases productivity of labor (e.g., large machinery). Under poor economic conditions, declining populations can also lead to the consolidation of farmland, farm abandonment, and selling land.

Meanwhile across most of East Africa, rural population growth rates are expected to grow, but the growth rate will continue to slow. When the agricultural population stops growing, a shift of labor towards the industry and service sectors is expected with important implications for the evolution of farming systems and food security (Tiffen 2003). The rural population had been providing a market for the urban industry and service sectors, and the urban areas had been the main market for farmers. Currently, many East African countries are in an acceleration phase of this transition from labor being mostly in agriculture, to being in industry and service. This is a critical time when investment needs to occur to improve agricultural productivity. Farmers need to invest in their farms to adjust to this lower level of labor and rising demand for higher-value food products. Examples include irrigation, labor saving equipment, animals, land preparation technologies, and crop inputs. Unlike investment in industry, this is often done at the small scale. Whether and how this occurs depends on the policy and market context.

1.7.4. Migration drivers and consequences

In addition to natural increase, the second component of population dynamics is migration. In East Africa, as in many developing regions, this process is not well researched and often underestimated. The impacts on both the origin and destination areas can be large, however. Rural areas are profoundly affected by the out-migration of its young people moving to urban centers or to seek opportunities in other rural areas. In-migration to rural areas can be rapid, introduce people from other ethnic groups into a previously closed society, and can cause shifts in access to land and other resources. Large and rapid migration to urban centers can cause environmental, infrastructure and societal problems, though urban migrants have been found to be usually better off than their non-migratory rural peers. Nonetheless, migration is often related to people seeking important, new economic or educational opportunities. Migration is associated with economic development processes such as urbanization, and the shift from agriculture to industry and service sectors. It is also associated with climatic shocks such as drought and floods and with civil unrest and war.

1.7.4.a. International migration

Statistics of internal migration (movement within the country) are difficult to find. Although population censuses often ask where people were born or lived previously, the results are often not published. International migration, however, of people coming into or leaving a country, is documented by the United Nations. Figure 1.7.4.a. illustrates the scale of external, net migration (immigrants minus emigrants) for each of the selected countries during three periods from 1980-1990, 1990-2000, and 2000-2010. Tables 1.7.2a and 1.7.2b display data from the United Nations Population Division (UNPD) on the scale of international migration in related to total population throughout the region in East Africa.[3] The impact of war, civil strife and genocide are visible in the large numbers of emigrants leaving Rwanda (early 1990s), Mozambique (1980s) and Ethiopia (1970s). Mostly, though, countries have migration patterns that

[3] The UNPD defines a migrant as someone who is not living in their place of birth.

reflect changing economic and political situations. In the most recent decade, all except Burundi and Malawi had net out-migration from 2000-2010.

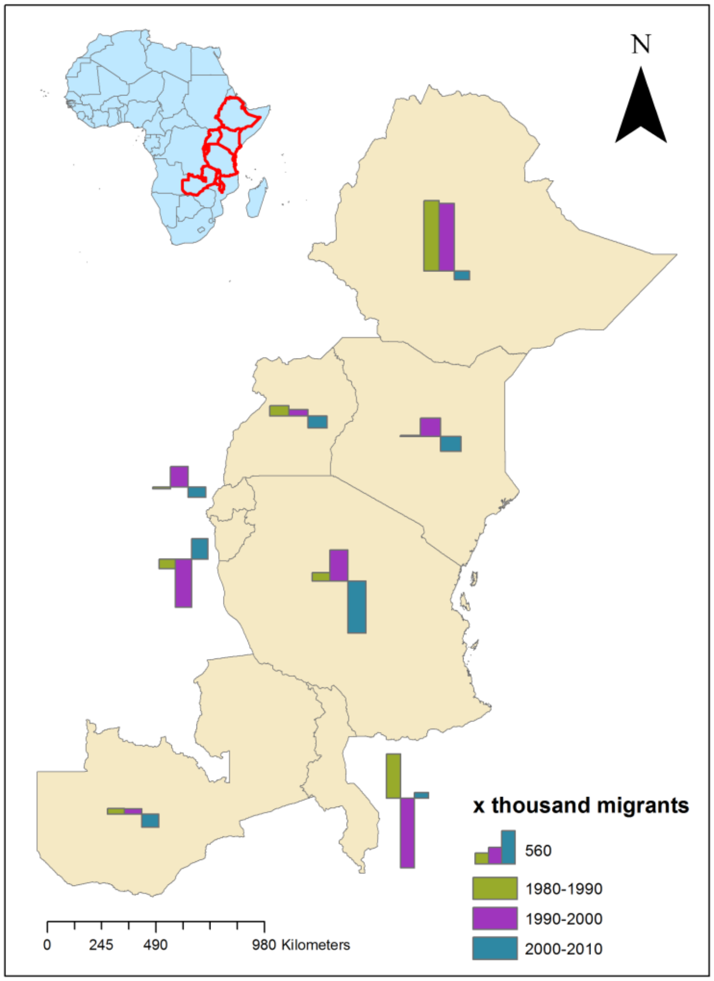


Figure 1.7.4.a. Net international migrants in selected countries in East Africa. Data source: UNEP 2013.

Table 1.7.2a. Net number of international migrants (in thousands) in East Africa, 1975-2010.

Major area, region, or country *	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005	2005-2010
Sub-Saharan Africa	-1 167	-1 662	-1 412	- 450	-1 137	- 429	- 184
AFRICA	-2 494	-2 578	-2 434	-1 015	-3 417	-2 099	-1 779
Eastern Africa	- 665	- 881	- 294	-2 395	856	- 781	- 879
Burundi	- 150	- 86	- 44	- 250	- 405	113	164
Ethiopia	-2 025	250	780	1 295	- 306	- 83	- 50
Kenya	- 3	4	5	222	- 21	25	- 189
Malawi	0	- 84	785	- 933	- 179	- 22	111
Mozambique	87	- 373	-1 300	650	75	- 20	- 20
Rwanda	- 20	- 50	30	-1 533	1 791	- 64	- 64
Uganda	- 167	- 115	233	120	- 46	- 5	- 135
United Republic of Tanzania	- 22	37	68	591	- 206	- 345	- 300
Zambia	4	48	29	- 11	83	- 82	- 85

Data source: U.N. 2013.

Note: Net number of migrants: the number of immigrants minus the number of emigrants. It is expressed as thousands.

Table 1.7.2b. Net migration rate (per 1,000 population) in East Africa, 1975-2010.

Major area, region, country or area *	**1975-1980**	**1980-1985**	**1985-1990**	**1990-1995**	**1995-2000**	**2000-2005**	**2005-2010**
Sub-Saharan Africa	- 1	- 1	- 1	- 0	- 0	- 0	- 0
AFRICA	- 1	- 1	- 1	- 0	- 1	- 0	- 0
Eastern Africa	- 1	- 1	- 0	- 2	1	- 1	- 1
Burundi	- 8	- 4	- 2	- 8	- 13	3	4
Ethiopia	- 12	1	4	5	- 1	- 0	- 0
Kenya	- 0	0	0	2	- 0	0	- 1
Malawi	0	- 2	19	- 19	- 3	- 0	2
Mozambique	2	- 6	- 19	9	1	- 0	- 0
Rwanda	- 1	- 2	1	- 48	51	- 1	- 1
Uganda	- 3	- 2	3	1	- 0	- 0	- 1
United Republic of Tanzania	- 0	0	1	4	- 1	- 2	- 1
Zambia	0	2	1	- 0	2	- 2	- 1

Source: U.N. 2013.

Note: Net migration rate: the number of immigrants minus the number of emigrant over a period, divided by the person-years lived by the population of the receiving country over that period. It is expressed as average annual net number of migrants per 1,000 population.

In the following sections, we will focus on internal rural-to-rural and rural-to-urban migration, as well as refugee settlements. Both theoretical explanations and empirical evidence on causes and implications of migration are reviewed.

1.7.4.b. Internal rural-rural migration

Rural-rural migration is an important response and adaptation to the effects of poverty and pressure on agricultural land (Ezra and Kiros, 2001; Potts, 2006). Rural-rural movements in East Africa are usually economically motivated by people seeking opportunities in the form of land to cultivate or to graze their livestock, or employment in mines or as agricultural laborers. They often seek more fertile soil, higher rainfall or larger plots of farmland or pastureland than they have in their origin (Potts, 2006; Ssengonzi, De Jong and Stokes, 2002). Others are seasonal or permanent labor migrants to mines or commercial farms, which produce cotton, coffee, tobacco, tea and other cash crops (Ezra, 2003). Spatial patterns vary by country. In Ethiopia, for example, most rural-rural migration occurs with population shifts from the northeastern to central and southwestern regions, or from the highlands and midlands to the lowlands (Ezra, 2003). In Malawi, rural-rural migration patterns primarily consist of movement from the Southern to the Northern Region (Potts, 2006).

The decision to migrate occurs as a result of complex social and demographic variables and influences, with individual, household and community characteristics playing a significant role (Ezra and Kiros, 2001). Many permanent rural-rural migrants are young people from small farms or from landless families. Others are better established and able to invest in land or other resources in another area, while maintaining their original farm. Fewer women tend to migrate, especially temporarily. The likelihood of a woman becoming a migrant is significantly affected by the number of children she has, the degree of education, marital status, age, and ethnic affiliation (Brockerhoff and Eu, 1993). This conclusion is based on the 1986-1990 USAID Demographic and Health Surveys (DHS) in 8 African countries, i.e., Burundi, Ghana, Kenya, Mali, Nigeria, Senegal, Togo, Uganda.

While neither ethnicity nor religion generally plays a significant role in an individual's decision to migrate, inter-family relationships weigh in, specifically the relationship of the migrant to the head of the household (Ezra, 2003). Age is also a significant determinant in migration and young adults between the ages of 15 to 29 have a higher propensity toward mobility (UNPD, 2008). Educational attainment impacts the decision to migrate; both migrant women and men in Africa usually have higher levels of educational attainment than their non-migrant counterparts (UNPD, 2008). Although data indicating the ratio between males and females participating in rural-rural migration are inconsistent, the available data does seem to consistently indicate that when reasons for migration are taken into account, more men are migrating in response to economic drivers while women predominantly migrate for other reasons, such as marriage (Ezra, 2003; Ezra and Kiros, 2001).

According to the United Nations Population Division, "In 26 of the 46 countries with data available on female migrants, <u>rural-rural migration is the most common and it tends to be the highest in Africa"</u> (2008, p. 18, emphasis added). Although the number of women who are migrating is increasing, female mobility is often restricted by cultural norms which tend to be more rigid in rural areas, including family caring and reproductive responsibilities and whether or not it is acceptable for women to travel on their own (IOMb, 2013). Cultural barriers and gender biases towards women in East Africa significantly restrict their ability to access land or credit. Despite the important contributions of female farmers to the agricultural sector in East Africa, they are often marginalized in their ability to participate in and benefit from the agricultural sector. Male household heads are given preferential treatment as landowners over resource-poor women. Migration is frequently viewed by women as a method of escaping traditional gender roles and discrimination and as an opportunity for empowering women, granting them to access to jobs and opportunities outside the home that otherwise would be unavailable to them (IOMb, 2013; Woldu, Tadesse, and Waller, 2013; UNPD, 2008).

In rural-rural migration, there is significant overlap of economic and environmental drivers, as the livelihoods of those who are migrating tend to be intrinsically connected to the environment. Migration allows the opportunity to diversify income or build resiliency while continuing to seek land-based livelihoods in the areas of destination (Black et al, 2011a). For many years, migration has been a response to severe climatic conditions, such as drought. However, it is widely anticipated that future climate change may amplify migration in East Africa where the majority of the population is dependent on rain-fed agriculture. The rural population is highly vulnerable to the impacts of future climate change, which is anticipated to impact agricultural production through increased climate volatility, reduced agricultural productivity and ultimately increased poverty (Ahmed et al, 2011; Conway and Schipper, 2011; Gray and Mueller, 2012; Moore et al. 2011). Indeed, according to farmers in southern Zambia and northern Tanzania, out-migration is already occurring from areas that have been experiencing prolonged, reduced rainfall (Mulenga 2012, Olson 2013).

Land degradation, as defined by the Food and Agriculture Organization of the United Nations, is the temporary or permanent lowering of the productive capacity of land and includes (among many forms) soil degradation, adverse impacts on water resources, deforestation, and less productive capacity of rangelands (FAO, 2013a). The extent of land degradation in East Africa is difficult to ascertain, but soil erosion and nutrient depletion, among other forms of land degradation, lower productivity. Land degradation often affects the poorest farmers due to their lack of resources to prevent or mitigate it, and the resultant low productivity can force them to seek alternative sources of income (Berry et al. 2004). It thus has a direct impact on the livelihoods of smallholder agriculturalists and serves indirectly as a rural-rural migration driver (Gray, 2011).

Population shifts in East Africa by way of rural-rural migration have implications for both the receiving and sending communities. There is great potential for increased stress on land in receiving areas, which may in turn augment deforestation and other problems associated with land degradation. In-migration can lead to greater competition for existing natural resources such as arable land, grazing land, and water, and may increase the potential for conflict (Black et al., 2011b; Raleigh, 2011). The out-migration of men from agricultural areas has resulted in an increased number of women-headed households in sending communities. In some areas in Kenya, women-headed households make up over 30% all households. Women who are left in charge of households are expected to perform both their traditional roles and take on additional responsibilities typically conducted by men, such as caring for animals and preparing the land for planting. This shift is contributing to challenging and changing of traditional roles as sending households and communities face a shrinking labor force. Ultimately, some regard this as contributing to the empowerment of women through increased autonomy and decision-making power (IOMb, 2013). Throughout

East Africa, the rural population tends to be clustered in higher potential areas, and this has led to localized high population densities and few opportunities for young people to obtain land. Rural-rural migration is an option for alleviating this and is widely viewed to have positive implications for the welfare of rural communities (Potts, 2006).

Agriculture is the dominant economic activity in East Africa: in Tanzania, for example, agriculture accounts for about half of gross production and employs about 80 percent of the labor force (Ahmed et al., 2011). Low yielding crop and livestock agricultural methods, including rainfed cropping with few inputs, are practiced by most farmers (Ahmed et al, 2011; Ezra, 2003). There are often few family resources to use in emergencies or in years of bad harvests. Rural-rural migration is widely viewed as a coping strategy for these types of economic and environmental problems (Potts, 2006).

Technologies and strategies to increase productivity and address the constraints of declining land availability can be a viable alternative to migration (Potts, 2006). In Malawi, for example, programs to intensify the agricultural system have focused on intercropping a variety of species (as many as four to twenty species) of legumes and maize (Peters, 2006; Potts, 2006). Although such technologies exist that could double yields, greater challenges faced by farmers include unequal distribution of land, lack of access to credit, and the high cost of fertilizer (Potts, 2006). Another technology to increase productivity locally, especially helpful in reducing the impact of climate change, is rainwater harvesting. This is becoming more common throughout East Africa, particularly in areas prone to recurrent drought. It is being used to provide irrigation water for high value crops, to water animals, as well as to minimize the impact of droughts and generally to alleviate food insecurity. Rainwater can be stored in above ground tanks, underground tanks, surface ponds, sand or subsurface dams, and shallow or hang dug wells. It is believed to be assisting in the raising of the water table in some communities (FAO, 2013a).

Income diversification and shifting emphasis among livelihood strategies in rural areas is another method to lower the “push’ factor leading to out-migration. It can reduce vulnerability to environmental conditions and improve resiliency throughout the region (Grogan, Birch-Thomsen and Lyimo, 2013). Currently, the non-farm economy in Sub-Saharan Africa accounts for approximately 35% of rural income. It is dominated by trade, transport, construction, and other services that are often seasonal and tend to fluctuate with the availability of raw agricultural materials (Haggblade, Hazell and Reardon, 2009). Employment outside of the agricultural sector – though frequently part-time and seasonal – stimulates income growth in rural areas and provides an alternative for smallholder agricultural laborers facing challenges, such as the increasingly commercialized and capital-intensive modes of farming (Haggblade, Hazell and Reardon, 2009).

Rural-rural migration as a trend in population mobility is anticipated to continue as it is widely regarded as resulting in improvements in the standard of living (de Brauw, Mueller, and Woldehanna, 2013). The amount of available land for new migrants is, however, becoming increasingly limited. A land use change model using United Nations population growth projections and other information estimated where people would clear new land. It indicated that all of the arable land in Uganda, Kenya, Rwanda and Burundi would be cultivated by 2025, whereas Tanzania would still have land left (Zambia and Malawi were not part of the exercise) (Washington-Ottombre et al. 2010).

Despite being perhaps the most common form of migration in East Africa, a comprehensive understanding of rural-rural migration is still widely impeded by the lack of research and empirical evidence. While academic interests have primarily focused on urbanization and rural-urban migration, most internal migration in East Africa occurs from one rural area to another and accounts for up to 80% of population mobility in some areas of the region. As a result of perhaps being the least studied variation of population dynamics, the limited data and evidence base in this field are varied and inconsistent (Black et al, 2011b; Ezra, 2003; Ezra and Kiros, 2001; Potts, 2006; Ssengonzi, De Jong and Stokes, 2002). A better developed understanding of the drivers and implications of rural-rural migration would assist policy makers in the future to enact effective policy pertaining to both climate change and rural development (de Brauw, Mueller, and Woldehanna, 2013).

1.7.4.c. Internal rural-urban migration

Population is indeed evolving rapidly in East Africa, and rural-urban migration and urbanization stands out as one of the most dramatic processes (Djurfeldt et al, 2013; McGranahan et al, 2009; Potts 2009& 2012). It is, however, a relatively recent phenomenon compared to other regions of the world.

Sub-Saharan Africa (SSA) had 37% percent of its population in urban areas in 2010, which is the second lowest globally only before South Asia. Within SSA, East Africa has the lowest percentage, of 24%. Urbanization rates range from 11% (Burundi – 2011) to 39% (Zambia – 2011) (Table 1.7.3). The region has, however, been experiencing faster urban growth than other low-income regions, with annual growth rates ranging from 3.6% to 5.9% (World Bank, 2013a). Currently, in our selected Feed-the-Future countries, there are 22 cities with populations over 100,000 (Figure 1.7.4.b.).

Table 1.7.3. Urban population of East African countries (1980-2011)

		1980	1990	2000	2010	2011
Urban population	Burundi	179201	351284	525629	892103	937095
	Ethiopia	3687876	6100141	9665526	13899855	14420416
	Kenya	2534974	3926933	6216986	9549244	9979760
	Malawi	564711	1084431	1640521	2316038	2414123
	Rwanda	244497	385053	1115304	1998375	2092204
	Tanzania	2719717	4811450	7593573	11783826	12359932
	Uganda	953965	1960421	2925429	5066513	5376189
	Zambia	2299382	3097411	3550348	5005752	5277522
Urban population (% of total)	Burundi	4.3	6.3	8.2	10.6	10.9
	Ethiopia	10.4	12.6	14.7	16.8	17.0
	Kenya	15.6	16.7	19.9	23.6	24.0
	Malawi	9.1	11.6	14.6	15.5	15.7
	Rwanda	4.7	5.4	13.8	18.8	19.1
	Tanzania	14.6	18.9	22.3	26.3	26.7
	Uganda	7.5	11.1	12.1	15.2	15.6
	Zambia	39.8	39.4	34.8	38.7	39.2
Urban population growth (annual %)	Burundi	8.1	5.8	4.0	5.0	4.9
	Ethiopia	3.7	5.2	3.9	3.4	3.7
	Kenya	7.3	4.2	4.2	4.2	4.4
	Malawi	6.1	6.0	4.6	3.8	4.1
	Rwanda	6.4	1.1	14.9	4.3	4.6
	Tanzania	7.9	5.5	4.1	4.6	4.8
	Uganda	4.3	7.1	3.8	5.8	5.9
	Zambia	5.8	2.6	1.2	2.7	5.3

Source: World Bank. 2013. World Development Indicator.

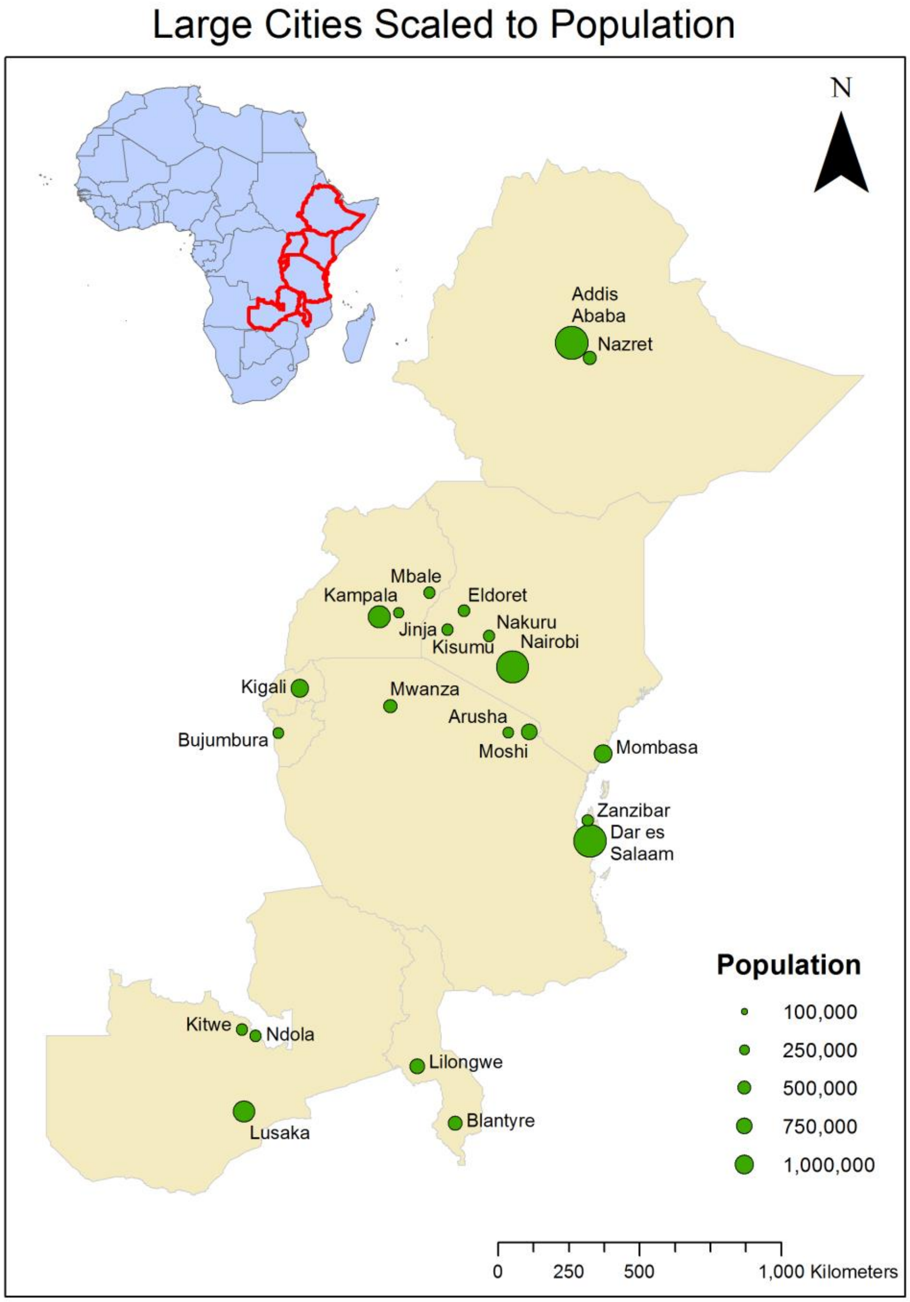


Figure 1.7.4.b. Large cities in selected countries in Africa, 2008. Data source: ESRI 2013.

African urban growth is mostly composed of local, natural increase (McGranahan et al, 2009) related to high fertility rates (Vimard 2008), not to in-migration. However, falling urban fertility rates have been confirmed in several countries in the recent Demographic Health Surveys, which may lead to lower population growth rates in the cities (Potts 2009; Potts 2012). While rural-urban migration constituted an important portion of urban growth in the 1960s and 1970s (about 40%) (Tacoli, 2001), its importance as a source of growth has decreased. In the 1980s, natural increase accounted for 75% of the urban growth (McGranahan et al, 2009). The decline in rural-urban migration as a source of urban growth can be attributed to the shrinking of the proportion of rural population over time, and a perception of urban economic misfortune (Djurfeldt and Jirström. 2013; Mabogunje 2007). Figure 1.7.4.c illustrates the impact of these trends on the population growth rates in urban and rural zones (note the different scales on the vertical axis). Migration to cities from rural areas is significant and is expected to continue to be high in the future. The population growth rate in rural areas started to decline in 2000 and is expected to be near zero (low or no growth) by 2050. Urban population growth rates have been as high as 10 percent, and are expected to level off at a very high rate of four up to 2050. The result is that by 2050, the urban and rural population sizes in most East African countries are expected to be the same (i.e., as many people live in cities as in rural areas).

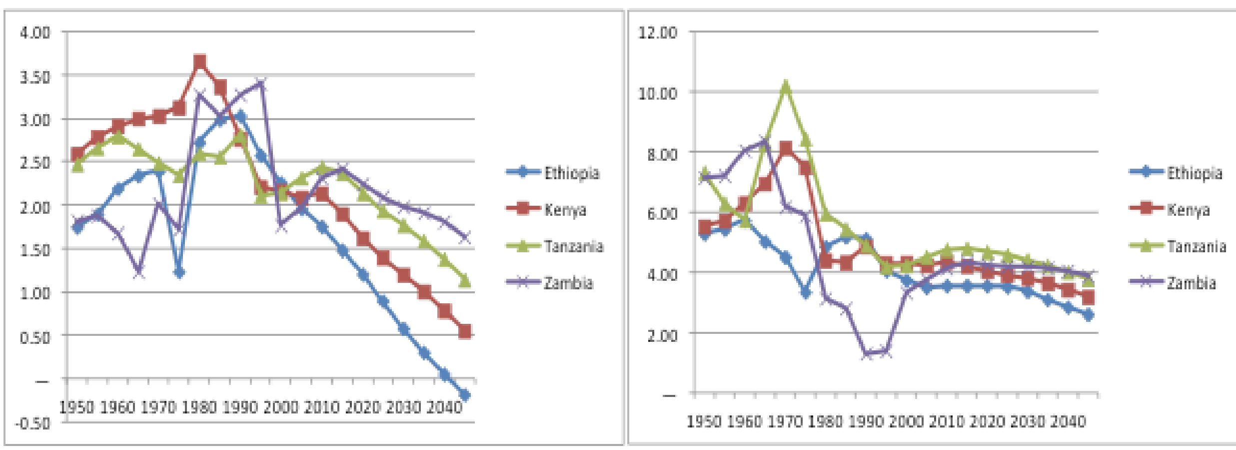


Figure 1.7.4.c. Population growth rates in rural (left) and urban (right) areas, 1950 to 2050. Data source: UN 2013.

In contrast to urbanization in developed or emerging countries where urbanization is driven by economic development, rural-urban migration in Sub-Saharan Africa is seen as primarily driven not by the pull of employment but the push of rural poverty (Djurfeldt et al, 2013; Nyakaana et al, 2007), including frequent droughts and low agricultural production due to declining precipitation (Barrios et al, 2006). The rural-urban migration does result in a significant amount of remittances sent to rural areas, some of which are invested in agriculture (Greiner and Sakdapolrak, 2012).

The rapid growth and informal natural of urban settlements, especially by recent migrants, is leading to the settlements having insufficient and often unsafe infrastructure. This can be aggravated by climate change and extremes. Dar es Salaam, Tanzania, for example has become home to large numbers of rural migrants who have moved into low lying informal settlements that frequently flood and are poorly protected from climate change-induced rising sea levels (Kebede and Nicholls, 2012).

1.7.5. Theoretical models explaining migration in Africa

Three models are often used to explain rural-urban migration in Africa and elsewhere (Arthur, 1991). First is the seminal work of Todaro (1969, 1971) who views the decision to migrate as a result of an individual's cost-benefit calculation based on the expected, rather than actual, rural-urban income differentials. Secondly, Mabogunje's 1970 system model takes a rather macro approach and concludes that rural-urban migration in Africa is driven by the systematic interrelationships of the rural/urban control systems, rural/urban adjustment mechanisms, and the positive or negative flow of information about migration. The two control systems include the rural one controlling outflows and the urban one controlling inflows. In this model, the background environment includes social and economic conditions, government policies, transportation, communications infrastructures, and the level of technology and development. Thirdly, Byerlee's 1974 model not only considers migration as the outcome of cost-benefit calculation of an individual, but also includes elements of the social system, various determinants of rural and urban incomes, and introduces risks and other psychic costs into the migration decision-making process (Byerlee, 1974: 556).

The relationship between the processes of population change and development in developing countries since WWII has been examined by several authors including Zelinsky (1971), Grigg (1980) and Gould (2009). Gould (2009) summarizes their approach in which the demographic transition, which describes how birth and death rates change with development, is taken a step farther to include how migration patterns go through a "mobility transition" with economic development. It describes how flows change from short distance or even international employment seeking, to being primarily towards frontiers to seek new land, to rural-urban movements, and finally to urban-urban flows and labor circulation. This trend is apparent in East Africa, with most countries still experiencing rural-rural or frontierward movements, but with rural-urban flows also important. In East Africa, the rate of fronteirward movements would be expected to soon decline rapidly while rural-urban movements would be expected to rapidly increase with economic development. They discuss how rural development activities, including family planning programs, land tenure reforms, Green Revolution technologies, and rural schools would affect rural out-migration in the short and long term.

Climate change is already an important push factor affecting rural-urban migration significantly in SSA. Econometric analysis based on a cross-country panel data set (1960-1990, 78 developing countries, with 34 SSA countries) found that climate change, indicated by decreasing rainfall, has led to increasing rates of urbanization in SSA, whereas there is no evidence of this in the rest of the developing world (Barrios et al, 2006). Other rural push factors in SSA have been identified including include poor management of water and land resources reducing agricultural production, displacement of people due to dam construction, poor irrigation practices exacerbating the water shortage, the land tenure system leading to disincentives to investing in long-term sustainable agricultural practices, and land grabs displacing subsistence farmers (Coleman, 2011).

Responses to these and other push factors in rural areas include diversification of income sources and locations (developing multi-location/ multi-sector activities) (Barker and Aina, 1995; Krokfors, 1995). Households in SSA more than elsewhere tend to rely on social network ties during rural-urban migration to deal with uncertainties in the migration process (Hoben and Hefner, 1991; Krokfors, 1995).

1.7.6. Refugees

According to the World Bank, East Africa has a significant number of refugees, defined by the United Nations as people who have left their home country due to persecution or fear of persecution (Table 1.7.4). Among them, Kenya hosts the largest refugee population, followed by Ethiopia, Tanzania and Uganda. The numbers shift widely from year to year due to shocks in their home countries and, in part, to adjustments in individual refugee status. For example, some people are resettled in a third country whereas others are repatriated or no longer categorized as refugees. Therefore, people may still be residing in the country but are not counted as refugees. The statistics do not include internally displaced persons (IDPs) or so-called climate refugees who are fleeing the effects of droughts or floods.

Table 1.7.4. Refugees in East Africa

	2008	2009	2010	2011
Burundi	21,093	24,967	29,365	35,659
Ethiopia	83,583	121,886	154,295	288,844
Kenya	32,0605	358,928	402,905	566,487
Malawi	4,175	5,443	5,740	6,308
Rwanda	55,062	54,016	55,398	55,325
Tanzania	321,909	118,731	109,286	131,243
Uganda	162,132	127,345	135,801	139,448
Zambia	83,485	56,785	47,857	45,632

Data source: World Bank, 2013.

The refugees hosted in East Africa are coming primarily from Uganda, Rwanda, and Ethiopia. Refugees from other countries such as the Democratic Republic of Congo, Central African Republic, and Eritrea have also sought refuge in East African countries (UNHCR 2012). Often, populations move through multiple countries, such as the 1972 Burundian refugee migration flow situated in Rwandan refugee camps until the genocide in 1994, after which the Burundians moved to Tanzania (Nawyn et al. 2012). Currently, Kenya and Ethiopia host the largest number of refugees. In Kenya, the majority of refugees are from Somalia, but also hosted are people from Ethiopia and Sudan. In Ethiopia, most refugees are from Somalia, Sudan, and Eritrea (UNHCR 2012).

Table 1.7.5. Refugees by Country of Origin, East and Horn of Africa.

Country of Origin	**1993-1997**	**1998-2002**	**2003-2007**	**2008-2012**
Burundi	281,592	94,239	84,064	101,288
Ethiopia	63,878	62,889	68,848	70,610
Kenya	9,688	9,620	8,602	8,745
Malawi	106	130	171	222
Rwanda	72,530	129,109	114,836	106,833
Tanzania	1,270	1,204	1,144	1,163
Uganda	7,548	7,554	6,441	5,680
Zambia	195	206	228	240

* Country of origin refers to citizenship or nationality of refugee
Data source: World Bank 2013.

The cause of the large number of people fleeing their homes can be a combination of political, social and economic factors leading to insecurity and high vulnerability, with a drought or other extreme climatic event bringing the situation to a crisis level. As early as 1990, the Intergovernmental Panel on Climate Change (IPCC) stated that "one of the greatest effects of climate change may be those on human migration" (IOMa, 2013). The scale of climate-induced, estimated migration is quite alarming, conservatively estimated at 25 million globally (IOM, 2013). Future migration estimates range from 250 million (Christian Aid, 2007) to 1 billion (IOMa, 2013) persons by 2050. It is less clear that climate change or climatic extremes may cause conflict. Some authors connect climate change to violent conflict that induces migration, although others question such a direct causal linkage (Samaan, 2011; Theisen et al., 2011/12).

Intractable and well-known problems

- Conflicts that lead to refugee migrations
    - Disrupts existing farming practices
    - Separates people from land ownership/control
- Long-term refugee camps and settlements
    - Stressors on food supply, dependence upon food aid
    - Refugees sell World Food Programme rations to purchase other needed items (Agier 2011) – not sure we know how this is affecting local food systems

Intractable but lesser-known problems

- Insufficient resources provided to refugee farm settlements
    - UNHCR reports indicate that the settlements are self-sufficient (measured by being cut-off from international aid), but other observers suggest that the people in these settlements are struggling immensely. During the first year of the Chogo settlement in Tanzania, at least 40 people starved to death (Grace 2013).
- Migration of refugees (usually men) illegally from camps and settlements to urban areas
    - Camp-to-urban migration necessary to maintain households
    - Presents stresses on resources (resulting in violence and discrimination against refugees; Malkki 1995; Sommers 2001)
- Insufficient data on production within refugee farming settlements
    - UNHCR reports claim that these farms are producing surplus crops ("Comprehensive Solutions for Burundian Refugees in Tanzania's Old Settlements," available at http://www.unhcr.org/cgi-bin/texis/vtx/home/opendocPDFViewer.html?docid=47b1a2522&query=

settlements%20tanzania), but the report provides no evidence to support that claim and it provides no indication of the crops that are grown.

Novel ideas that might be actionable

- Better data are needed regarding the agricultural productivity of refugee settlements. Evaluations require study from independent observers rather than evaluators hired by UNHCR.
- In studies of resilience, refugees will be a particularly important population to study, given their established resilience post-resettlement (Luster et al. 2009) and within camps, contrary to the myth that refugees develop dependence or learned helplessness (Agier 2011; Kibreab 1993). We know little about which survival strategies refugees use in different regional and settlement contexts (namely the agricultural techniques they use, how they use food rations, and the role of rural-to-urban migration plays in the survival of refugee households in camps and settlements).

Finally, a case in point is that crops that may proliferate in extreme weather conditions may not be suitable for populations that are highly mobile, such as refugees. For example, bitter cassava is a crop that grows well in drought conditions. However, it must be processed carefully using a process that eliminates the naturally occurring cyanide in the plant. This process takes approximately two days to complete. People fleeing their homes quickly under threat of violence have been consuming bitter cassava without the necessary processing, leading to increased incidents of konzo, a disease caused by cyanide poisoning which leaves the sufferer with lower extremity paralysis. This problem has been widely documented in the Democratic Republic of Congo and the Central African Republic (Banea et al., 2012; Ciglenečki et al. 2011), but may be indicative of problems related to forced displacement and food security in East Africa as well.

1.7.7. Summary of migration and farming systems

In summary, what is known about the drivers of migration in East Africa is the following:

1. The economic viability of farming and livestock keeping in the origin and destination areas:
    a. Availability of land for young people to inherit or otherwise access, and the agro-ecological potential of that land.
    b. Climatic or other shocks (e.g., droughts, conflict) leading to sudden out-migration.
    c. The existence of, and distance to, a market for trading commodities (high-value exports versus low-value locally traded).
    d. Availability of infrastructure and services: transport, communications, education, extension, etc.

2. Availability of non-farm income opportunities locally or ability to link to income sources elsewhere.

3. The perception of available employment, education or other opportunities in urban areas or other rural areas.

The impact of out-migration on the origin rural areas includes a change in the composition of households and communities. Most temporary migrants are young men or some young women, whereas many permanent migrants are young couples or families. The community left behind tends eventually to be more biased towards older people and children, with less labor available for agricultural work. In areas of high out-migration, population growth may be slowed. When men leave their wives and families behind, these households tend to become (if they aren't already) among the poorest in the community with little land, capital or labor resources to invest in the farm. Some out-migrant men are, however, relatively wealthy pursuing additional income, and these households tend to maintain their wealth.

The rural destination areas receiving migrants are the zones with the most rapid land use change in East Africa as land is converted from savanna, woodland or forest usually to seasonal crops. The impact on the environment, including biodiversity and vegetative cover, can be dramatic and itself lead to a drying of the local and regional climate (Moore et al. 2011). The farming system in these newly farmed areas is often initially extensive, with relatively large farms and low labor input. Investment in irrigation, animals and other technologies, however, can occur where markets and environmental conditions support higher value commodities.

1.7.8. Discussion and conclusion

The link between population dynamics, the evolving farming system and external factors such as climate change and the economy in East Africa have been summarized above. In short, population changes reflect wider societal and economic changes in society, and the impact of those population changes on rural and urban systems are enormous. How farming systems evolve with changes in population – successful or unsuccessful intensification and extensification – depends in large part on the policy and economic context. Meanwhile, climate change and variability is already affecting these patterns. Increasingly drier conditions in some semi-arid zones are leading to out-migration, and droughts in combination with other vulnerabilities are related to refugee movements.

The relationship between population dynamics and related land and economic factors provide insights into the type of adaptation technologies or coping strategies that might be most suitable and adopted. Conditions of the relative value of land, labor and capital, and, of course, the economic profitability of any required investment including in labor, affect the potential utility of a technology or strategy. These conditions vary by agro-ecological zone, farming system and location relative to markets. However, they also vary by household and even individual within the household. There is no gender, wealth, age, farm size or other "neutral" technology. The questions to consider are: what are the main factors affecting the economic and social viability of agricultural innovations? What type of "innovations" might be most successful? Where and for whom?

While the literature has established strong correlations between climate change and population dynamics, especially migration, there remains a need to evaluate the causative relationship between climate and migration; these relationships are challenging to demonstrate due to the inconclusive evidence from past studies, the complexity of the relationships between different factors, and the lack of micro-datasets that can attend to different environmental and social conditions (Mendola, 2012; Black et al, 2008; Byerlee; 1974; Mabogunje, 1970; Todaro, 1969 & 1971). Difficulties in predicting the impacts of climate change on population movements can also be attributed to the high level of uncertainty and unpredictability about the specific effects of climate change, and the lack of comprehensive data on urbanization and migration flows (Tacoli, 2009; Djurfeldt et al, 2013). This is particularly true for marginalized urban migrants such as refugees, who may actively hide their presence in urban centers in order to avoid harassment and violence (Grace, 2013; Sommers, 2001). Nevertheless, the literature has sufficiently demonstrated that the impacts of climate change on population dynamics are mediated by vulnerability, resilience, and resources of the affected individuals, communities, regions, and nation-states (Hugo, 2012). It is vulnerable people, especially those disadvantaged by income, gender, race/ethnicity, and other marginalized statuses in the climate hot spots of the Global South that are most adversely affected by climate change (Resurreccion and Sajor, 2012).

Yet vulnerability and adaptation as socially differentiating process and dynamics have not received sufficient attention. Despite the potential of many existing social theories, measures to increase the capacity of the most vulnerable to improve their own situation and approaches to increase available resources and improve governance in the domain of climate-induced migration remain to be uncovered. Further, while women are particularly vulnerable to gender-based discrimination and marginalization within patriarchal kin relations, their capacity to reconfigure their marginalization in adaptive ways is just beginning to be studied (Gabrielsson and Ramasar, 2012; Resurreccior and Sajor, 2012). We, therefore, seek innovative solutions, including policies, mechanisms, and organizations, to address the empowerment of migrants, the equitability of migration, and forced resettlements in climate hot spots of East Africa. Specifically, we are interested in addressing the following concerns:

- Better measures of population growth and movement
    - More reliable data on who engages in rural-rural and rural-urban migration
    - Household- and community-level effects of remittances of migrants on agricultural practices that respond well (or not) to climate changes
    - Mobilize rural-urban resource networks to improve how agricultural practices in sending communities respond to climate change
- Empowerment of migrants through social networks to achieve economic viability
    - Innovative solutions to strengthen migrant social networks at rural origins and its impact on agricultural production

        - Innovative solutions to re-establish social networks at urban/rural destinations and how that can be a source for economic development both at sources and destinations

- Enhance the equitability of migration, especially those that incorporate a gender analysis, to increase the economic viability and adaptation of the vulnerable population and household

    - Analysis and policy actions to understand migration as a gendered process and how that affects food production through analyzing different patterns, drivers and impacts on men and women, and the relationship between the role and status of woman in the region and gendered migration

    - Transformation and policy actions to address social practices that discriminate certain migrants based on gender and other social/cultural norms

- Better understanding of the main factors affecting the economic and social utility and viability of agricultural innovations, such as those that reduce climate change vulnerability.

    - What type of "innovations" might be most successful, where and for whom? For example, compare farming systems, ties to the market, gender considerations, and labor constraints.

    - How will population dynamics affect these factors in the medium and long term?

- Refugee settlement/resettlement

    - Effective resettlement assessment: well-being/quality of life of pre- and post-resettlement

    - Effective measures to address insufficient funding and misallocation of resources, including design of international scheme

    - Innovative bottom-up approaches to empower displaced households and communities

1.8. Gender

Gender is a central organizing principle of society, and it governs the division of roles and responsibilities as well as the allocation of production resources. Gender-based inequalities and gendered social roles impact women's ability to cope with the effects of climate change, with the most significant impact being felt in women's access to resources (e.g. agriculture extension services, land, etc.) (Habtezion, 2012). For example, due to 'customary tenure', men often have greater control and decision-making power over land and crops (Bernier et al., 2013).

Gender disparities in access to productive resources and political participation have been well-documented across Southern and Eastern African, although specific differences and drivers vary from country to country. Institutions (e.g., financial, socio-cultural, and legal) also shape the lives of men and women by creating and maintaining inequitable or equitable access and opportunity. Several studies have determined that due to gender inequities in resources, roles and responsibilities, men and women will not experience climate changes equally, and that adaptation measures will need to take gender differences into account to avoid exacerbating inequalities in the face of these long-term shifts in the climate. FAO (2011) notes that the abilities of men and women to adapt to climate shocks and long-term climate changes differ because of unequal access to entitlements, assets, and decision-making power. For example, women receive only 5% of agriculture extension services worldwide (FAO, 1993). Additionally, only 15% of African landowners are women; the number of small-holders who have access to credit is lower than that of men, and women are less likely to use inputs such as fertilizer and improved seeds or use mechanical tools and equipment (FAO, 2011). Female farmers are also overwhelmingly excluded from many communication channels when it comes to climate-related information (McOmber et al., 2013). For example, Kyazze et al. (2012) found that, in the Rakai district of Uganda, alternative methods of communication, such as megaphones and public announcements, should be used to disseminate climate-related information to women, rather than more recent methods such as cell phones and radios.

In spite of the consensus in the literature on gender, agriculture, and climate change that climate change impacts are likely to be gendered, and that awareness of the consequences of these differences can and should be incorporated into research/program design and implementation, there is an overall lack of gender analysis in systematically analyzing how gender roles and responsibilities, gender relations and particularly how gender-asset/resource gaps influence vulnerability and adaptation to climate change. Even more, empirical evidence on the gender-differentiated impact of climate change is also lacking. These knowledge gaps are particularly critical for Southern and Eastern Africa given the well-documented gender disparities, rural poverty, and climate change threats.

Olson et al. (2010) conducted a desk study review of the growing development literature on gender, agriculture, and climate change by key donors, universities, and research organizations. First, they found significant gender differences in access to productive assets that could inhibit growth-enhancing or climate-adaptive investments. With respect to land, they observed that many studies have found that women hold formal title to fewer land parcels than men, and those who do own land typically have smaller plots. Although formal legal systems may give equal rights to land to men and women, in practice and in customary systems, men are typically favored over women in land allocation (FAO 2011). For example, in 2004 in Kenya, one study attributes only 1% of land titles to women (Institute of Economic Affairs-Kenya 2008). In Tanzania, where the 1999 land law overrides customary law if it denies women their right to use, transfer and own land and women's rights of co-occupancy are also protected, the 2003 agriculture census still reported that average land size is one-third lower in households headed by women than those headed by men (1.6 ha to 2.7 ha) (Tripp n.d.; United Republic of Tanzania 2007). In Uganda, in spite of the coexistence of multiple systems of land ownership, customary law favors men and is preferred in rural areas, with mixed consequences for women at different life stages (Tripp n.d.). Second, they found that gaps in knowledge about gender relations could affect program design, monitoring, or evaluation, particularly related to climate change. They note that there are critical gaps in knowledge of the specific impacts of climate change on vulnerable locations and groups, both in terms of the way that climate variability will intersect with rural gendered activities as well as the level and type of information to which men and women have access. They conclude that gaining a better picture of the gender dimensions of climate change impacts could lead to more locally appropriate and effective, gender sensitive programs.

Rubin (2012) conducted a gender assessment for agriculture and climate change for USAID/East Africa. She observed that one of the key areas relevant to USAID/East Africa's areas of focus where sex-disaggregated data and gender analysis are limited is with the potential gendered impact of regional climate change policies and programs. As a recommendation, she identified the need to improve sex-disaggregated data collection and analysis relevant to improved policy making. In addition, she observed a need to incorporate sex-disaggregated data into models of climate change-motivated migration patterns and vulnerability assessments.

Gender analysis involves collecting and analyzing sex-disaggregated data (on both men and women) and other qualitative and quantitative information on gender issues, including access to and control over assets (tangible and intangible), beliefs, behaviors, and legal or institutional frameworks. The collection of sex-disaggregated data is the initial and very important first step in conducting a gender analysis. Agriculture and climate change related research informed by sound evidence from gender analysis are critical for the development of gender-responsive adaptation practices and climate change policies and programs. The lack of sex disaggregated climate change related data has severely limited the ability to incorporate gender analysis into research. East African studies focused on climate change adaptation and agriculture that have collected sex-disaggregated data are limited in number (Swai et al., 2012; Kyazze et al., 2012; Nelson & Stathers, 2009; Chaudhury et al., 2012). Climate change related research devoid of gender analysis could result in gender-blind policies and innovations, i.e. policies and innovations that are not sensitive to the needs of men and women farmers. According to Swai et al. (2012), gender-blind climate change policies have the potential to further widen gender disparities. Some limitations include: decreased rates of 'adaptive innovation', increased food insecurity, lower incomes, increased time spent performing domestic chores such as fetching water and fuel, increased vulnerability if not given equal access to climate-related information, and increased risk of bearing the burdens of droughts and floods (Ashby et al., 2012).

Recently, research methods such as participatory action research have begun to be used to understand the relationship between gender, agriculture, climate change, and adaptation. For instance, Nelson & Chaudhury (2012) developed a training guide "Gender and Climate Change Research in Agriculture and Food Security for Rural Development" to help practitioners and researchers. The goal of the aforementioned training guide is to "promote gender-responsive and socially-sensitive climate change research and development in the agriculture and food security sectors through participatory approaches" (Nelson & Chaudhury, 2012, pg. 1). Such knowledge may also inform researchers and development practitioners of the specific causes of vulnerability (Nelson & Chaudhury, 2012). There is, therefore, a need to collect data from men and women on their roles and responsibilities, their access to critical adaptation resources (human, physical, social and financial), the different types of adaptation and mitigation strategies that they use, as well as differences in the ways they are impacted by climate shocks. Such information would be used for a gender analysis that would in turn serve as valuable input into any climate change related research.

1.9. GCFSI Programmatic Review

Efforts were made to identify future, ongoing, or completed research programs that overlap with the research presented in this volume (see Table 1.9 for details). Five intersecting topical areas of interest were identified including gender, migration, climate change pressure, land use, and water-related issues. Three similar but non-overlapping programs of note, *Africa RISING*, *USAID Modernizing Extension and Advisory Services (MEAS)*, and *UK Department for International Development (DFID) Research Into Use (RIU) Programme* were identified as potential areas of overlap and are discussed below.

There are several ongoing and completed USAID-funded programs with a gender component, but they appear to have no substantive overlap with this project. The *USAID African Women in Agriculture Research and Development (AWARD) Program* is ongoing and is dedicated to improving the research skills and leadership qualities necessary for successful researchers. *The USAID Asset Based Financing for Smallholder Farmers Program* is an ongoing effort that focuses on providing tools to improve farm income with the majority of the program's effect influencing women. These tools include fertilizer, seed, and training. *USAID Building Climate Change Resilience and Food Security among Small Holder Farmers in Semi-Arid Kenya Program* is an ongoing effort that introduces technologies and strategies to enhance food security. One completed program, *USAID Kenya Maize Development Program II*, was a business support and yield enhancement effort that targeted both women and children for improving sustainability and nutrition.

Efforts to identify research programs with a substantively similar migration component did not yield any overlapping efforts. Similarly, overlaps in programs looking at climate change pressure were absent, with the *USAID Building Climate Change Resilience and Food Security among Small Holder Farmers in Semi-Arid Kenya Program* deemed similar but without significant overlap.

No overlapping land use programs were evident. The *USAID/U.S. Geological Survey Agreement,* an ongoing effort to identify forest/land use and mining areas in Senegal has no potential overlap. *SERVIR Africa*, an ongoing project that combines satellite and sensor data with predictive modeling in order to monitor and predict ecological change, does not deal specifically with agricultural considerations but may result in products similar to those suggested here. Neither the ongoing *USAID Maize, Dairy, Soil Fertility & Nutribusiness Program* nor the completed *USAID Maize and Bean Research Program* overlap with the agricultural research discussed in this volume.

A great deal of water-related research was identified, reviewed and evaluated for potential overlap. Future efforts reviewed include the *ZAMBIA: FY 2011–2015 Multi-*

Year Strategy, TANZANIA: FY 2011–2015 Multi-Year Strategy, KENYA: FY 2011–2015 Multi-Year Strategy, ETHIOPIA: FY 2011–2015 Multi-Year Strategy, and the USAID Water Strategy 2013-2018. Ongoing programs reviewed include the *International Federation of Red Cross and Red Crescent Societies (IFRC) Zambezi River Basin Initiative, CARE Drought Mitigation through Irrigation Promotion & Conservation Agriculture Extension II (DICE II), Integrated Food Security and Risk Management (INFORM), USAID Productive Safety Net (ALT), USAID Global Hunger and Food Security Research Strategy: Climate Resilience, Nutrition, and Policy (RFA-OAA-12-000036), USAID Public-Private Alliances Related to Water Access (M-OAA-GRO-EGAS-08-108-ETHIOPIA-WATER), USAID Kenya Arid Lands Disaster Risk Reduction-WASH Program (RFA-623-12-000005),* and *USAID Pastoralist Areas Water, Sanitation and Hygiene Program (RFA-663-11-000007).* None of these programs were found to have existing significant overlaps. Completed programs reviewed include the *Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN) Treadle Pump Irrigation Programs in Zambia, EnterpriseWorks/VITA Tanzania Small-Scale Irrigation Project* and *the CARE Water, Sanitation and Education for Health (WASH) Project*.

As mentioned above, *Africa RISING, USAID MEAS, and UK DFID RIU* were not found to have any research overlaps. *Africa RISING*, a research project that focuses on regional aspects of development, does not have similar overarching research concerns. *USAID MEAS*, an ongoing project looking at Sub-Saharan economic development and food security does not specifically address climate change as a core element. Finally, *UK DFID RIU* is a completed project that does not programmatically incorporate climate change into its research objectives. This review of future, ongoing, and completed projects indicates that while there is much research dedicated toward natural and social aspects of development and sustainability in Eastern and Southern Africa, no projects substantively focus on the same concerns proposed in this volume. Understanding how gender, migration, climate change pressure, land use, and water-related issues operate in concert to affect agricultural sustainability in the face of climate change is essential if we are to manage the challenges presented moving forward.

Table 1.9. Programmatic comparisons

Subject	Program	Disposition and Comments	Agency/Source
Gender	USAID African Women in Agriculture Research and Development (AWARD)	ONGOING: This program has a gender component but does not explicitly deal with climate change and agriculture. AWARD strengthens the research and leadership skills of African women in agriculture science. This program focuses on professional women, leaving out very important audiences such as women who own small-holder farms.	http://portfolio.usaid.gov/ProjectDetail?id=a0cd00000011ujvAAA
	USAID Asset Based Financing for Smallholder Farmers Program	ONGOING: This program does not explicitly deal with climate change and agriculture. It helps small-holder farmers in Western Kenya double their farm income per acre by focusing on increasing access to farm inputs, finance, and market facilitation. Most project participants are women.	http://portfolio.usaid.gov/ProjectDetail?id=a0cd00000011uk0AAA
	USAID Kenya Maize Development Program II	COMPLETED: This program has a gender component but does not explicitly deal with climate change and agriculture. The project works to raise agricultural productivity, improving the effectiveness of smallholder organizations and increasing their access to agricultural markets and business support services.	http://portfolio.usaid.gov/ProjectDetail?id=a0cd0000000am0yAAA
	USAID Building Climate Change Resilience and Food Security among Small Holder Farmers in Semi-Arid Kenya	ONGOING: This program has a gender component but does not explicitly deal with climate change and agriculture. The overall goal of the program is to build climate change resilience and food security in small farming households. To do this, climate change adaptive technologies and risk reducing practices will be used.	http://portfolio.usaid.gov/ProjectDetail?id=a0cd000000125FGAAY
Migration	N/A	N/A	N/A

Subject	Program	Disposition and Comments	Agency/Source
Climate change pressures	USAID Building Climate Change Resilience and Food Security among Small Holder Farmers in Semi-Arid Kenya	ONGOING: Related but no overlap. See gender component description above for more information on this program.	http://portfolio.usaid.gov/ProjectDetail?id=a0cd000000125FGAAY
Land use	USAID/U.S. Geological Survey Agreement	ONGOING: Use of remote sensing to identify forest/land use, mining and land cover. 1) Focuses on Senegal, 2) Project description is extremely vague.	http://portfolio.usaid.gov/ProjectDetail?id=a0cd0000002JleRAAS
	USAID Maize and Bean Research	COMPLETED: Improves agricultural activities in Uganda. Project primarily focuses on maize and bean crops.	http://portfolio.usaid.gov/ProjectDetail?id=a0cd0000000am8GAAQ
	USAID Maize, Dairy, Soil Fertility & Nutribusiness Program	ONGOING: Improves agricultural activities in Kenya. Project focuses on improving technology and crop varieties.	http://portfolio.usaid.gov/ProjectDetail?id=a0cd0000000am0gAAA
	SERVIR Africa	ONGOING: Project integrates satellite observations and predictive models with other geographic information (sensor and field-based) to monitor and forecast ecological changes. 1) Implementation is proceeding in a phased approach. The first phase is devoted to identification of geospatial portal requirements, prioritizing activities, and pursuing a gradual process of SERVIR community-building. 2) Initial applications	http://www.servir.net/africa/index.php?option=com_content&task=view&id=26&Itemid=46

Subject	Program	Disposition and Comments	Agency/Source
		will address three societal benefit areas: disasters (flood potential mapping, flood forecasting, and post-event flood mapping), health (Rift Valley Fever risk mapping), and biodiversity (impacts of climate change on biodiversity and coral reef monitoring). No mention of agriculture.	
Water	Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN) Treadle Pump Irrigation Programs in Zambia	COMPLETED: Under CARE's leadership of the initiative, CLUSA and IDE delivered over 300 treadle pumps within the target area from December 2005 through August 2006.	http://www.fanrpan.org/documents/d00493/
	EnterpriseWorks/VITA Tanzania Small-Scale Irrigation Project	COMPLETED: Project objective was to promote treadle pump and tube-wells for small-scale irrigation.	http://www.enterpriseworks.org/
	CARE Water, sanitation and education for health (WASH) project	COMPLETED: Project promoted small-scale irrigation for rice and horticultural crops.	http://www.care.org/careswork/projects/SOM080.asp
	International	ONGOING: This three-year initiative aims to reduce the risk	http://www.ifrc.or

Subject	Program	Disposition and Comments	Agency/Source
	Federation of Red Cross and Red Crescent Societies (IFRC) Zambezi River Basin Initiative	and impact of flooding in the seven countries—Angola, Botswana, Malawi, Mozambique, Namibia, Zambia, and Zimbabwe—encompassing the Zambezi River basin. For the benefit of more than 235,000 people in the region, the project promotes conservation agriculture, natural resource management, small-scale irrigation, and the use of flood- and drought-tolerant seed varieties.	g/ar/news-and-media/press-releases/general/red-cross-to-launch-historic-zambezi-river-basin-initiative/
	CARE Drought Mitigation through Irrigation Promotion & Conservation Agriculture Extension II (DICE II)	ONGOING: The project aims to extend drought mitigation approaches refined during previous programs, including the original DICE program, to approximately 20,000 people in the Dowa, Ntcheu, and Salima districts in Malawi's Central Region. Interventions include establishing small-scale irrigation schemes, introducing conservation agriculture techniques, enacting savings-and-loan groups, and strengthening local early warning systems.	http://www.care.org/careswork/projects/MWI044.asp
	Integrated Food Security and Risk Management (INFORM)	ONGOING: USAID/OFDA is providing additional support to continue a Concern-implemented, community-led disaster and natural resource management program in Western Province, Zambia. The project is building and maintaining the capacity of community- and district-level disaster management committees to prevent, mitigate, and respond to the impacts of disasters. The program also encourages farmers to use natural resources sustainably by promoting conservation agriculture and developing small-scale irrigation systems, both of which mitigate the livelihood impacts of drought. In total, the project is expected to benefit approximately 178,000 people.	http://sa.usaid.gov/southern_africa/node/86
	USAID	ONGOING: Food aid assistance to the Ethiopian Government's	http://ethiopia.us

Subject	Program	Disposition and Comments	Agency/Source
	Productive Safety Net (ALT)	multi-donor program improve livelihoods of 2.3 million of the most vulnerable Ethiopians via food for rural works such as water harvesting structures, farm-to-market roads, school and health clinic construction, and land reclamation.	aid.gov/programs/feed-future-initiative/projects/productive-safety-net-program-psnp
	USAID Global Hunger and Food Security Research Strategy: Climate Resilience, Nutrition, and Policy (RFA-OAA-12-000036)	ONGOING: Program Areas: 1) High-Yielding, Climate-Resilient Legumes (two distinct opportunities: soy and other legumes); 2) High-Yielding, Climate-Resilient Cereals; 3) Increased Livestock Productivity through Climate Resilience and Disease Resistance (two distinct opportunities: vaccine development and breeding/genomics approaches); 4) Small-Scale Irrigation Technologies and Agricultural Water Management Practices; 5) Reduced Post-Harvest Losses and Food Waste; and 6) Food Security Policy.	http://www.feedthefuture.gov/article/feed-future-launches-request-applications-climate-resilience-nutrition-and-policy-research
	USAID Public-Private Alliances Related to Water Access (M-OAA-GRO-EGAS-08-108-ETHIOPIA-WATER)	ONGOING: Approximately $250,000 total is set aside for public-private-alliances to support USAID/Ethiopia's market-led livelihoods and economic growth programming to improve agricultural productivity and watershed management through improved water access. USAID/Ethiopia encourages submission of concept papers to support public-private alliances. Particular focus should be placed on multi-use water access for production, livestock, and drinking water and sanitation.	http://ethiopia.usaid.gov/newsroom/news/new-model-public-private-partnership-boost-production-and-incomes-35000-ethiopian-maiz
	USAID Kenya Arid Lands Disaster Risk Reduction-WASH Program	ONGOING: Through its investments, USAID proposes the following objectives: 1) Increase water storage capacity in arid lands, through improving natural and artificial storage. 2) Improve WASH conditions at health facilities and nutrition centers frequently utilized during emergency response. 3) Improve access to safe drinking water sources, improve access	http://vprgs.msu.edu/funding-opportunity/usaid-rfa-623-12-000005-kenya-arid-lands-

Subject	Program	Disposition and Comments	Agency/Source
	(RFA-623-12-000005)	to and usage of point of use water treatment products, promote good hygiene behaviors and use of sanitation facilities as a means of reducing diarrheal disease in areas with recurrent emergency levels of malnutrition and around areas of improved water storage.	disaster-risk-reduction-wash-program
	USAID Pastoralist Areas Water, Sanitation and Hygiene Program (RFA-663-11-000007)	ONGOING: USAID/Ethiopia seeks to support the objectives of this Pastoralist Area Water, Sanitation, and Hygiene Project which are: 1) to increase access to water for target communities; 2) to improve hygiene awareness and access to sanitation among beneficiaries; and 3) to improve rangeland land management practices. The key intervention areas and activities are: 1) drilling 22 new boreholes and installing water supply systems for human/animal use (13 in Somali, 6 in Afar and 3 in Oromia); 2) rehabilitation of 19 existing boreholes for human/animal use (10 in Somali, 6 in Afar and 3 in Oromia); 3) promotion of community water management including proper well management and maintenance as well as capacity building for managing the environs surrounding the water source i.e. natural resource and land use management training, do no harm training to mainstream conflict approach in the planning, implementation and evaluation of the facilities; 4)improving hygiene awareness and sanitation among beneficiaries through training of Woreda (District) Health Agents, Health Extension Workers and volunteer hygiene promoters; and 5)community and household latrine and sanitation facility construction.	http://ethiopia.usaid.gov/programs/global-health-initiative/projects/water-sanitation-and-hygiene-transformation-enhanced-resi
USAID Water/Irrigation Related Future Strategies	ZAMBIA: FY 2011–2015 Multi-Year Strategy	FUTURE: FTF in Zambia supports peri-urban smallholders to grow vegetables more profitably by promoting out-grower schemes, linking smallholders to processers (value addition activities), and supporting access to improved irrigation and other technologies.	http://www.feedthefuture.gov/sites/default/files/country/strategies/files/ZambiaFTFMulti-YearStrategy.pdf

Subject	Program	Disposition and Comments	Agency/Source
	TANZANIA: FY 2011–2015 Multi-Year Strategy	FUTURE: Irrigated agriculture will be promoted to improve productivity and to mitigate the impacts of climate change. The target is to increase the area under irrigation in Tanzania by 15.5 percent, from 306,000 ha to 353,000 ha, through development of smallholder irrigation schemes in Morogoro and Zanzibar.	http://www.feedthefuture.gov/sites/default/files/country/strategies/files/TanzaniaFTFMulti-YearStrategy.pdf
	KENYA: FY 2011–2015 Multi-Year Strategy	FUTURE: To advance the development of irrigation and support this new focus. The Mission will coordinate with and leverage funds from the WASH Program and incorporate water conservation and efficiency practices to maximize use of water resources for both potable and productive uses	http://kenya.usaid.gov/sites/default/files/KenyaFTFMulti-YearStrategy.pdf
	ETHIOPIA: FY 2011–2015 Multi-Year Strategy	FUTURE: Attention will be given to agricultural inputs (seed and fertilizer); improved rainfed agronomic methods; irrigation and improved water-use efficiency; natural resource conservation; livestock and forage development; and strengthening research-extension-farmer linkages. In the moisture deficit areas (i.e., Hungry Ethiopia), the focus will be on soil and water conservation and watershed management using labor-based methods. Attention will be given to water utilization, development alternative livelihoods, productive safety net initiatives to underpin food security for vulnerable households, nutrition, and climate change adaptation. In pastoral areas (i.e., Pastoral Ethiopia), the focus will be on livestock development, water for people and livestock, forage development, irrigation, improving the livestock marketing system, nutrition, and climate change adaptation.	http://ethiopia.usaid.gov/sites/default/files/images/USAID_FtF_MYS.pdf
	USAID Water Strategy 2013-2018	FUTURE: IR 2.1: Improve the efficiency and sustainability of food production from rainfed agricultural systems. Support for small-scale, often privately and farmer-owned, micro-irrigation as a point of investment has the potential to impact millions of farmers in sub-Saharan Africa and Asia and drive significant improvements in crop yields in smallholder	http://www.usaid.gov/documents/1865/usaid-water-and-development-strategy-2013-

Subject	Program	Disposition and Comments	Agency/Source
		agriculture. The majority of the Feed the Future investments to increase agricultural production are in areas where farmers rely on rainfed agriculture, with significant small-scale irrigation efforts ongoing in Tanzania, Ghana, Mali, Tajikistan, Haiti, and Ethiopia that include rehabilitation of defunct irrigation schemes. In places like Cambodia, Ethiopia, and Kenya, where climate change is increasing the severity of dry conditions in the dry season, USAID is helping rainfed agricultural systems incorporate supplemental irrigation measures.	2018
Related Programs of Note	Africa RISING (Research In Sustainable Intensification for the Next Generation) Program	ONGOING: Current Africa RISING efforts focus on regional research for development (R4D) issues, where the GFSCI research scope identifies opportunities for overarching research themes that complement both existing and emerging efforts.	http://africa-rising.net/
	USAID Modernizing Extension and Advisory Services (MEAS)	ONGOING: MEAS is engaged in outreach that supports economic development and food security in Sub-Saharan Africa; however, the program does not explicitly list climate change as a primary variable of concern.	http://www.meas-extension.org/
	UK Department for International Development (DFID) Research Into Use (RIU)	COMPLETED: RIU research is engaged in disseminating innovation in regional agricultural research but does not programmatically incorporate climate change as an area of primary concern.	http://researchintouse.com/

Subject	Program	Disposition and Comments	Agency/Source
	Programme		

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