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Shared climate change and natural resource management issues in East Africa

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Question

Please provide an overview of the most significant shared climate change and natural resource management issues across the East Africa region.

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1. Summary

This review uses a mixture of academic and grey literature to explore key shared climate change and natural resource management issues across the East Africa region.[1] Climate change involves different impacts (flood, drought, changing rainfall patterns, etc.) which simultaneously affect numerous issue-areas (agriculture, transport, energy production, etc.), different levels of society (ranging from local to regional), across different spatial and temporal scales. Because of these multi-faceted characteristics, discussing the socioeconomic impacts of climate change is very complex. Given the limited time available for this review and the interrelated nature of climate change and its impacts, it was necessary to narrow the focus of this paper down to some key issues. The issues selected were highlighted through an initial scoping of the literature and by the DFID advisers who requested this review. This review aims to provide a general overview of the literature and is not exhaustive or complete in the issues it focuses on, nor does it make a judgement on the importance of these issues over other climate change related issues in the region. This review provides a brief discussion of the observed and projected climate changes for the East Africa region. Some key economic and social impacts of climate change that are broadly shared by the countries in the East Africa region are then highlighted. The areas explored for East Africa in this review include: drylands management, pastoralism and agriculture; urbanisation and flooding; water availability and supply; forestry and ecosystem changes. The literature reviewed illustrates how complicated and at times speculative the expected socioeconomic impacts of climate change are.

Key findings include:

- The East and Horn of Africa are characterised by great climatological variability and weather diversity as caused by the complex topography, latitudinal location and effects from regional and global atmospheric circulation. Rainfall and temperature are the two most important climatic variables and exert significant impacts on human livelihoods, socioeconomic development and ecosystems in the region.
- Climate modelling indicates that East Africa is expected to warm in the coming decades, although changes in rainfall are less certain. Extreme rainfall events will likely become more intense and frequent by the end of this century, and dry spells may increase.
- Drought, flooding, rainfall variability and resource degradation are key climate-related social-ecological risks in East Africa. These challenges are likely to be exacerbated by rapid population growth and by the urbanisation projected for this region in the coming decades. Poor households are the most vulnerable to the adverse impacts of climate change and natural resource changes. Vulnerability is highly differentiated socially, in terms of both exposure and underlying susceptibility.
- The prevalence of droughts is a key problem in the East and Horn of Africa, and have caused major economic and humanitarian impacts during the last four to five decades by affecting rain-fed agriculture and pastoralism, the backbone of these economies.
- The number of people living in drylands in East Africa is projected to grow in the coming decades, putting increased pressure on an already vulnerable resource base. Despite the great uncertainties associated with future climate change in the East and Horn of

[1] For the purposes of this review, East and Horn of African countries are geographically grouped as Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Uganda, and Tanzania. Please note that some literature cited in this review may define these differently.

Africa, the projected increase in the frequency and severity of extreme weather events is expected to exacerbate the vulnerability of people living in drylands. However, the research on the impact of climate change on pastoralism in East Africa is not decisive and there is some consensus that the threat to pastoralists' wellbeing is not drought, but the increasing marginalisation of pastoralists' drought response mechanisms. This further highlights the complexity of the interface between climate change impacts and socioeconomic issues, and the inability to draw simple, linear conclusions.

- Flooding is a growing environmental and socioeconomic problem in East Africa particularly within lowland regions. With the prevalence and impact of flood hazards in urban areas showing increasing trends during the recent past, and flood events expected to increase in frequency and intensity in the future, cities in East Africa are predicted to experience some of the most severe impacts from climate extremes.
- Water is a key natural resource in East Africa, particularly given the region's reliance on agriculture for its economy and projections of rising demand. The uncertainty in climate projections in East Africa and the large uncertainties associated with hydrological models makes it difficult to predict the impacts of climate change on water resources with confidence. However, if there are to be more extended dry spells and a higher proportion of rainfall occurring as intense events, this could have a significant detrimental impact on the reliability of surface water stores, environmental flows, and soil water in East Africa.
- The forests of East Africa provide energy, food, timber, and non-timber forest products and contribute to wealth and health at the household, community, national, sub-regional, regional, and even global levels. Climate change will exacerbate the impacts of the processes that already stress and threaten overexploited ecosystems in East Africa for several reasons, including agricultural expansion, destruction of habitats, pollution, high rates of change in land use, and population growth.

There has been much research on climate change and natural resource issues in East Africa. Most of the literature reviewed was from peer-reviewed academic journals, although some grey literature was also included. Consensus on the impacts of climate change in East Africa is varied given the generally weak ability of global circulation models to agree on future precipitation changes in the East Africa region. However, there is stronger evidence for an increase in the frequency and intensity of extreme weather events in East Africa, which are a focus of the literature. There was a lot of research into the drylands and pastoralism in East Africa, however, the conclusions of these was varied in terms of the importance of climate change in affecting recent and future changes to livelihoods. Despite the wealth of research reported for the drylands of East Africa, deficiencies in knowledge on vulnerability and response to climate-related social-ecological risks remain diverse. The research agenda on urbanisation in sub-Saharan Africa appears to have increased in recent years, especially with a focus on flooding and the impacts of this in cities. Water supply and variability in East Africa has long been researched, but expected impacts of climate change are uncertain. Fewer academic papers could be found in relation to forestry and ecosystems in East Africa. A number of gaps were highlighted in the literature, including the timing and interactions of different climatic stresses on plant growth and development, and the impacts on crops, livestock and farming systems of changes in climate variability and extreme events. The ways that the distinctive characteristics of African urban development create and manage risk are poorly understood, and there is a need for empirical evidence on the generation and reduction of risk at the city scale. Much, but not all, of the literature considered gender issues, especially in relation to urbanisation and the gendered differentiation of vulnerability, both in terms of susceptibilities and capacities.

2. Observed and projected climate change

The East and Horn of Africa are characterised by great climatological and weather diversity and variability as caused by the complex topography, latitudinal location and effects from regional and global atmospheric circulation (Degefu et al., 2018). Rainfall and temperature are the two most important climatic variables displaying high levels of changeability across a range of spatial and temporal scales in the East and Horn of Africa, and create diverse ecological and livelihood zones (Degefu et al., 2018: p.20; Omondi et al., 2014). The impact and risks of rainfall variability is more significant than temperature in the region (Degefu et al., 2018: p.20). Due to the complex nature of the East and Horn of African climate, most impacts are felt at local and regional levels.

East Africa's climate is already changing. The equatorial and southern parts of eastern Africa have experienced a significant increase in temperatures since the early 1980s, and seasonal average temperatures have risen in many parts of the region over the past 50 years. Rainfall in the region is extremely variable across time and space (Climate & Development Knowledge Network, 2014: p.p.12-14). There is a lack of evidence about observed trends in extreme temperatures, extreme rainfall, and drought in east Africa. However, droughts and storms have been more frequent in eastern Africa in the last 30–60 years. Changes in the Indo-Pacific oceans appear to have contributed to more frequent drought during the 'long rains' (from March to May) over the past 30 years. It is not clear whether these changes are due to human-caused climate change or to natural climatic variability (Climate & Development Knowledge Network, 2014: pp.10-11).

Climate modelling indicates that East Africa is expected to warm in the next 5-40 years, although changes in rainfall are much less certain. Maximum and minimum temperatures over equatorial East Africa will rise, and there will likely be an increase in warm days. The average annual temperature will likely increase by 1°C to 2.4°C by 2065. There will be a rise in warm nights in particular (an increase of about 8-12 days per decade), and warmer days will likely happen more often (Future Climate For Africa, 2016; Climate & Development Knowledge Network, 2014: p.18; IPCC, 2013).

Tropical rainfall changes are challenging to project. For eastern Africa, the 'long rains' season has recently experienced a series of devastating droughts, whilst most of the climate models predict increasing rainfall for the coming decades. This is the so-called 'east African climate change paradox' (Rowell and Chadwick, 2018). This may be explained by the difficulty in modelling the change, or that models do not incorporate all factors driving this change, and is an area of active research (see Rowell and Chadwick, 2018). Currently, global projections suggest that by the end of the 21st century, the climate in eastern Africa may be wetter or drier, but more likely to be wetter (with rainfall changing by between -6% and 17%) (Future Climate For Africa, 2016; IPCC, 2013). The projections suggest a wetter climate during October to December ('short rains'), and March to May ('long rains'). By 2050, the 'long rains' season may shorten for Ethiopia, Somalia, Tanzania, and southern Kenya. However, the 'short rains' season in southern Kenya and Tanzania may lengthen (Climate & Development Knowledge Network, 2014: p.18). Thus, for any specific location, predictions of the amplitude of rainfall change – and sometimes its sign (positive or negative) – are highly uncertain (Rowell and Chadwick, 2018). There will likely be more heavy rainfall over the region with high certainty and more extremely wet days by the mid-21st century. Extreme rain events over most of the mid-latitude land masses and over wet tropical regions will very likely become more intense and more frequent by the end of this

century, as temperatures warm, and dry spells may increase (Future Climate For Africa, 2016; IPCC, 2013).

The challenges associated with the impacts of climate change in East Africa are likely to be exacerbated by rapid population growth and by the urbanisation projected for this region in the coming decades. Poor households are the most vulnerable to the adverse impacts of climate change and natural resource changes. Hallegatte et al. (2017: pp. 4-5) identify five reasons why poor households are disproportionately affected by natural disasters:

i) Over exposure (poor households are more likely to live in areas or accommodation susceptible to regular events such as floods);
ii) Higher vulnerability (poor households typically suffer higher losses when natural disasters strike);
iii) Lower ability to cope and recover after an event (due largely to a lack of public support);
iv) Permanent impacts on education and health (a result of negative coping strategies); and
v) Lasting changes to behaviour (vulnerability to natural disasters deters poor households from investing in livelihoods).

Over the long term, poor households are less able to move or diversify their livelihoods in response to deterioration in their livelihoods resulting from climate change.

3. Economic and social impacts

Drylands management, pastoralism and agriculture

Rain-fed agriculture

In the East and Horn of Africa the link between climate and livelihood is very strong, as the majority of the East African community largely depends on rain-fed agriculture and other natural resource based livelihoods, which are highly vulnerable to the impacts of climate change (Adhikari et al., 2015; Degefu et al., 2018: p.16). Agriculture is a major source of food and contributor to the regional economy, responsible for 40% of Gross Domestic Product (GDP) in the region as a whole (Nyasimi et al., 2013 cited in Degefu et al., 2018), and over 75% of the labour force across the East and Horn of Africa is engaged in agriculture (Salami et al., 2010 cited in Degefu et al, 2018). Climate variability, mainly of rainfall (e.g. drought, flood, erratic rainfall and change in rainfall season), has negatively impacted agricultural production and water resources, which leads to scarcity of food, water and other environmental resources for human consumption. Among the various environmental changes brought about by climate change that limit crop yields, heat and water stresses are considered the most important (Prasad et al. 2008 cited in Adhikari et al., 2015). In high altitude regions such as mountainous lands in Ethiopia and Kenya, where temperature is the limiting factor for plant growth, a rise in temperature from climate change will possibly increase crop yield, but in lowland areas, it will increase the risk of water stress (Thornton et al. 2009 cited in Adhikari et al., 2015).

Drylands and pastoralism

Relevance of a changing climate

The drylands of the East and Horn of Africa are home to several million people, where livelihoods predominantly rely on pastoral farming and related activities. In recent years, the drylands have been exposed to multiple and complex climatic shocks particularly recurrent drought, which underlie chronic poverty, food insecurity, and rangeland degradation (Fitzgibbon and Crosskey, 2013 cited in Degefu et al., 2018: p.6). Most drylands[2] are marginal environments characterised by challenging agro-climatic conditions and endowed with limited resources to support primary production activities, such as livestock-keeping and farming, so they tend to be hotspots of natural resource degradation (Cervigni and Morris, 2016: p.30). The fragility of current livelihood strategies in drylands is often compounded by the social and political marginalisation of many of the groups that live in drylands, limiting their ability to influence political processes. Due to complex interactions among many different factors, vulnerability in the drylands is high and is rising, jeopardising the long-term livelihood prospects for millions of people. Despite the great uncertainties associated with future climate change in the East and Horn of Africa, climate change, which is expected to increase the frequency and severity of extreme weather events, will exacerbate this challenge. According to analysis by Cervigni and Morris (2016: p.2), by 2030 the population living in drylands in East and West Africa is expected to grow by 65–80% (depending on the fertility scenario), putting increased pressure on a resource base already severely stretched. Over the same period, climate change could result in an expansion of the area classified as drylands (up to 20% under some scenarios), bringing more people into environments in which livelihood options are limited and in which opportunities to ensure resilience are severely constrained (Cervigni and Morris, 2016: p.31).

Egeru (2016) examined pastoralists' perceptions of climate change, climate risk management information types, sources and attendant responses in a pastoral region of East Africa.[3] Through a multi-stage sampling process, a total of 198 heads of households in three districts were selected and interviewed using a semi-structured questionnaire. In addition, 29 focus group discussions and 10 key informant interviews were conducted to generate qualitative information to supplement survey data. Ninety-nine percent of the pastoralists noted that the climate had changed, evidenced by high but erratic rainfall, occurrence of floods and variation in rainfall onset and cessation among other indicators. This change in climate had led to the emergence of 'new' livestock and crop diseases, crop failure and low yields leading to frequent food shortages, water shortages, poor market access, and variation in pasture availability among other effects.

Lind et al. (2016) apply a conceptual approach (*Pastoralist Livelihood Systems Analysis*) to understand longer-term pathways for pastoral livelihoods and their consequences for poverty,

[2] There are a number of ways of defining drylands. Cervigni and Morris (2016) define drylands according to the widely used aridity index (AI), which is the ratio between average annual precipitation and potential evapotranspiration; drylands are lands with an AI of less than 0.65. Drylands are further divided into hyper-arid, arid, semi-arid and dry sub-humid. See http://www.fao.org/dryland-forestry/background/what-are-drylands/en/

[3] The study was undertaken in Karamoja sub-region of Uganda, which is inhabited by the pastoral Karamojong who form part of the larger Karamoja cluster (Nyangatom of Ethiopia, Toposa of South Sudan, Turkana in Kenya and the Karamojong of Uganda) in East Africa.

vulnerability and resilience in different areas of dryland eastern Africa.[4] The report adopts a focus on pastoralist systems. These refer to a production system centred on the rearing, marketing and trade in livestock and animal products. Pastoralist systems encapsulate a far wider range of non-livestock livelihoods and productive activities in dryland areas, which are also associated with pastoralism through a variety of social and economic relationships (Lind et al., 2016: p.3).

Lind et al. (2016) highlight how today there are a number of varieties of pastoralism: commercialised forms of livestock-keeping oriented to large domestic and regional export markets; smaller-scale livestock-keeping for subsistence and local marketing combined with farming and other rural activities; the maintenance of very few small-stock in and close to towns alongside the pursuit of various tasks-for-cash; and customary pastoralism based on long distance movements, key resource use, and maintaining a network of bond friendships through which to exchange livestock and labour as the basis for mitigating risk.

According to their review, the most significant trend redefining pastoralism in eastern Africa is the fragmentation of rangelands through processes of excision, privatisation (often taking the form of enclosures) and commodification of rangeland resources. They highlight that concerns around the potential impacts of climate change is a prominent theme in many resilience studies of pastoralism in East Africa, but that contradictory and varied rainfall trend-lines in the region place into question claims that global climate change is leading to irreversible changes in the resource base for pastoralism (Catley and Aklilu, 2013; Ericksen et al, 2013; Devereux, 2006 cited in Lind et al, 2016: p.22). The perception of many pastoralists that drought shocks are worsening should be understood in the context of increasing rangeland fragmentation and unequal access to resources, which restrict mobility and flexibility, thereby undermining adaptive capacities. Lind et al. (2016) highlight that the consensus of the literature is that the threat to pastoralists' wellbeing is not drought, but '*the increasing marginalization of pastoralists' drought response mechanisms*' (Yohannes 2012: 10, original emphasis; Kifie and Gebre-Michael 2009 cited in Lind et al., 2016: p.22).

Catley et al. (2016) review pastoralism in the Horn of Africa region[5] with reference to the basic socioeconomics of pastoralism, and the use of mobile livestock production to generate income and food for human consumption. In these dry areas, the strategic movement of livestock is a rational and productive response to uncertain availability of pasture and water, and includes substantial cross-border movements of animals. Catley et al. (2016: p.390) highlight examples that show that, across the region, there are very different pathways of pastoralism, associated with different futures. Pastoralism is performing well for some people in some areas. However, increasing numbers of people are also becoming impoverished or food insecure. The paper describes how long-term economic, environmental and demographic trends, as well as crises such as drought, determine how pastoralism and pastoralist areas change over time. A level of complexity relates to climate trends, with analysis of rainfall data indicating no long-term trend of diminishing rainfall in eastern Sudan or cross-border areas of Kenya, Ethiopia and Somalia, and

[4] The report focuses on five pastoralist systems to reflect the wide range of trajectories of pastoral systems in the region: Maasai system in Kenya's South Rift Valley, Somali region of Ethiopia, Borana Plateau in southern Ethiopia, Karamoja in northern Uganda, and Northern Bahr el Ghazal region in the greater Bahr el Ghazal livelihood zone of South Sudan.

[5] For Catley et al. (2016) this approximates to the region covered by the Intergovernmental Authority for Development (IGAD), with the Member States of Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan and Uganda (www.igad.int).

general uncertainty over future rainfall patterns. Nonetheless, at local and policy levels, there are many reports of increasing severity or frequency of drought in pastoralist areas. These reports, however, might be explained by the increasing impacts of drought, due to the rising number of vulnerable people in pastoralist areas who are exposed to them, rather than long-term trends in rainfall (Catley et al., 2016: 392).

In some areas, commercialised forms of pastoralism have evolved over decades and pastoralists are major suppliers of livestock to domestic and export markets. However, commercialisation is also associated with increasing private control of pasture and water which, when coupled with human population growth and recurrent drought, limits the future of poorer pastoralists. In other areas, reduced access of pastoralists to rangeland takes various forms, e.g. because of conflict and wildlife conservation, encroachment upon land by farmers, and land allocations for mechanised irrigation schemes and hydroelectric schemes (Catley et al, 2016: 398). When combined with limited market access, population growth, and drought, the outcome is a continuation of subsistence pastoralism for some, but increasing destitution for others. Catley et al. (2016: 398) conclude that pastoralism may offer different futures for different pastoralists in the Horn of Africa, but it has proven to be a remarkably robust and adaptable form of livestock production, and is still central to livelihoods in the region and will continue to dominate the economies of dryland areas.

Conflict

The eastern Africa region has been known for recurring drought, prolonged civil war and frequent pastoral conflicts. Climate and environmental factors have been presented as major triggers of conflicts among pastoralist communities, but others have challenged this. While various hypotheses exist for these phenomena, there is a growing consensus that environmental factors can increase the risk of violent conflict under certain circumstances (Faris, 2007; Ki-Moon, 2007; Sachs, 2006; Scheffran and Battaglini, 2011 cited in Ayana et al., 2016: p.602; van Baalen and Mobjörk, 2016). However, past studies have given mostly descriptive explanations for the causal relationship between environmental resource scarcity and pastoral conflict, but quantitative support for this hypothesis is lacking, and there has been a general lack of clear consensus. Ayana et al. (2016: p.601) used 29 years of georeferenced precipitation and Normalised Difference Vegetation Index (NDVI) data to evaluate long term trends in scarcity of water and forage for livestock in eastern Africa. They then looked at whether these environmental stressors had any predictive power with respect to the location and timing of 11 years of conflict data (based on Armed Conflict Location and Event Data Project and Uppsala Conflict Data Program). Ayana et al. (2016: p.609) found that data on patterns of precipitation and NDVI (forage) fail to explain pastoralist conflicts of east Africa. A major hurdle in connecting the onset of conflict with climate and environmental factors is the unpredictability of pastoralists' response to such stressors. The lag in a response to these environmental stressors depends on the coping mechanisms available to the pastoralists. Overall, their results indicated that environmental stressors were only partly predictive of conflict events, and further quantitative research into the contribution of other potential stressors is needed to better understand the drivers behind conflict (Ayana et al., 2016: p.601).

Van Baalen and Mobjörk (2016) undertook a systematic literature review of 44 academic articles that investigate the relationship between climate-related environmental change and violent conflict in East Africa. Their analysis shows that environmental changes such as changing rainfall patterns, droughts, changes in vegetation cover and increasing resource scarcity have contributed to various types of violent conflict in East Africa, and that the link is particularly

evident for conflicts involving livestock herders. However, they emphasise that this does not mean that climate-related environmental change automatically causes violent conflict – the political, economic and cultural context is often key. Their review reveals a need for researchers to not only take the social and political context into consideration, but also the temporal and spatial dimensions when analysing the linkages between climate-related environmental change and violent conflict. Climate change involves delayed effects and boundary crossing impacts, as do the dynamics of violent conflict. Mere correlation-based analyses limited to short periods or limited spatial units risk overlooking the complex relations that shape the causal pathways between environmental change and violent conflict (van Baalen and Mobjörk, 2016: p.2).

Need for more research

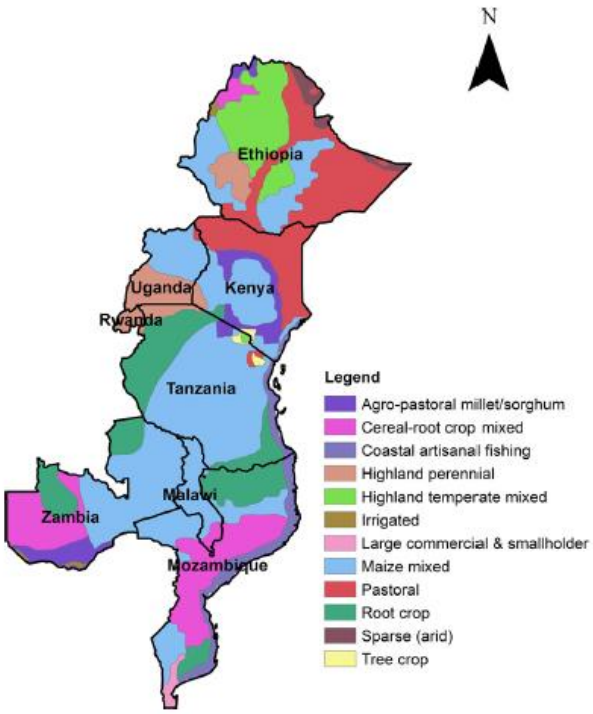
Key processes in the semi-arid lands of East Africa include transitions to agro-pastoralism, changes in land distribution, agro-industrial development, population growth, migration and urbanisation (Few et al., 2018: 10). Few et al. (2018) highlight the need for greater understanding of the social dynamics of pastoralism such as changing mobility patterns and of the trade-offs associated with these pastoral development trajectories. Several authors have stressed the importance of a more longitudinal analysis of the complex, interactive factors related to past and future pathways of change within the region's pastoral system (see e.g. Ericksen et al., 2013; Letai and Lind, 2013 cited in Few et al., 2018: p.13). Evidence remains patchy across the region as to the mechanisms, processes or factors determining whether poor pastoralists fall into poverty because of climatic shocks.

Impacts on crops and livestock

Smallholders who contribute up to 90% of agricultural production dominate agriculture in East African countries. As presented in Figure 1 below, the maize mixed cropping system covers over 40% of the area, followed by pastoral (14%), root crop (12%), and cereal-root crop mixed system (11%). Other major crops in the region include cassava, banana, and rice, while teff is a major crop in the Ethiopian highlands (Adhikari et al., 2015: p.111).

Adhikari et al. (2015) reviewed the impacts of climate change on fourteen staple and cash crops in sub-Saharan Africa, with a special focus on eight countries in East Africa (Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Tanzania, Uganda, and Zambia). The review of literature on the impacts of climate change on crops in East Africa suggested that wheat is likely to be the most negatively impacted crop (Adhikari et al., 2015: p.125). The paper finds that it is projected that wheat yield will decrease by up to 72% by the 2080s. Other grain crops such as maize, rice, millet and beans are projected to be moderately impacted. Sorghum is projected to be least impacted of the grain crops. Root crops are projected to be less impacted by climate change. Optimum production zones for tea and coffee are projected to decrease by as much as 40% due to rise in temperatures. Cotton and sugarcane are less sensitive to temperature rise, but more prone to drought stress under climate change (Adhikari et al., 2015: p.125).

Figure 1: Land use map of East Africa



Source: FAO, 2002 cited in Adhikari et al., 2015: p.111.

Escarcha et al. (2018) highlight how the future of the livestock sector globally will be increasingly challenging with the projected scarcity of resources crucial for production, particularly land and water, under climate change. Climate change leads to reductions in livestock productivity by directly depressing animals' adaptive response mechanisms, altering the spread and prevalence of diseases, and causing heat stress and related welfare issues; and indirectly by compromising the availability of feed crops and quality of forages. There are substantial research gaps in how livestock is impacted by climate change and how farmers and systems adapt, particularly at the impact and adaptation nexus (Escarcha et al., 2018: p.13).

Urbanisation and flooding

Flooding is a growing environmental and socioeconomic problem in East Africa particularly within lowland regions (see Degefu et al., 2018: p.15 for further references), with the prevalence and impact of flood hazards showing increasing trends during the recent past (Mulugeta *et al.*, 2007; Huho and Kosonei, 2014 cited in Degefu et al., 2018: p.17). Flooding is expected to increase in frequency and intensity with climate change, and will impact further on urban areas (Future Climate For Africa, 2016).

Cities in sub-Saharan Africa (including those in East Africa) are predicted to experience some of the most severe impacts from climate extremes, not least due to the low levels of adaptive capacity among urban populations. Dodman et al. (2017) present a critical review of African urbanism and urban change, and how these influence exposure to hazards of various types, and contribute to the vulnerability of individuals, households and communities. Their review highlights how risk production in urban centres is complex; it goes beyond only looking at hazards and vulnerability, to considering the multiple ways in which hazards are created and vulnerability is

shaped. Their analysis suggests that the distinctive traits of towns and cities in sub-Saharan Africa including fragmentation, violence, and fragility play a significant role in creating risk, but also offer considerable opportunity and potential for addressing it. Of particular importance to the increase of vulnerability and hazards in African cities are the nature of spatial expansion, the demographic profiles of cities, and the prevalence of informal economies and settlements (Dodman et al., 2017).

Although African urban contexts are highly varied, Africa's urban transformation is characterised by some key common features. The history and governance of the region is markedly different to other regions of the world, as is the scale and pace of the demographic, social, economic and political transitions African cities are experiencing, and the opportunities this presents for resilience building (Dodman et al., 2017: p.8). One key issue with urbanisation in sub-Saharan Africa is that population growth is occurring in an expansive rather than compact form, resulting in falling urban population densities and a higher rate of land use change than population growth rates alone might imply (Dodman et al., 2015: p.8). By significantly altering the natural landscape, the spatial expansion of African cities is causing myriad ecological impacts, including the alteration of hydrological cycles, habitat loss and increased pressure on forests and land. This environmental degradation generates new hazards such as landslides and flash flooding. Women's experiences in urban areas are highly varied and context specific, shaped by factors such as location, education levels, household profiles and wealth. Typically, however, gender norms and discrimination mean that women in African cities are likely to be more vulnerable to environmental hazards than men, and face additional socioeconomic challenges (Dodman et al., 2017: p.9).

Douglas (2017) highlights that flooding may occur many times a month in parts of many African cities, usually through rainfall that overflows from channels, or even does not reach defined channels. Heavy rain may also cause groundwater levels to rise to the surface, thus releasing subsurface water that begins to flood normally dry valley floors. Although the water is the immediate cause of inundation, the actual height and extent of any given flood is determined by the nature of the ground surface, the dimensions of the channels or coasts along which flood flows develop and by local obstructions to water movement. Such ground conditions are the products of many different human actions that change the land cover, alter the ability of water to infiltrate and impede the flow of water along channels. In built-up urban areas of Africa, inadequate drainage puts thousands at risk of flooding from frequent short duration, but high intensity, thunderstorm rains (Douglas, 2017).

The complex impacts of flooding on urban people stem from multiple causes operating at varying scales in different locations. Most urban social and environmental issues, including flooding, are interconnected. Their drivers and effects cross many time and space scales, these interdependent connections are now frequently termed ‘teleconnections’. Well-established climatic teleconnections are paralleled by teleconnections associated with land use and land cover changes, including those driven by mining, forestry, agriculture and urbanisation (Douglas, 2017). The examination of urban teleconnections can help to establish the effects of land use and land cover changes in one part of a river basin on water availability for irrigation or urban use, or on river channel capacity for flood waters, in another area further downstream (Douglas, 2017: p.35). The cumulative impacts of flooding weaken households, communities, cites and national economies (Douglas, 2017: p.38).

Henderson et al. (2017) document strong but differentiated links between climate and urbanisation in large panels of districts and cities in sub-Saharan Africa, which has dried

substantially in the past 50 years. The key dimension of heterogeneity is whether cities are likely to have manufacturing for export outside their regions, as opposed to being exclusively market towns providing local services to agricultural hinterlands. In regions where cities are likely to be manufacturing centres (25% of their sample), drier conditions increase urbanisation and total urban incomes. There, urban migration provides an 'escape' from the effect of deteriorating climate on agricultural productivity. However, in the remaining market towns (75% of their sample), cities just service agriculture. Reduced farm incomes from negative shocks reduce demand for urban services and derived demand for urban labour. There, drying has little impact on urbanisation or total urban incomes. Hence, they find that in sub-Saharan Africa, spatial and structural transformation driven by climate change will only be successful where cities can absorb the excess labour (Henderson et al., 2017: p.61).

Water availability and supply

USAID (2017) highlight that water is a key natural resource in East Africa, particularly given the region's reliance on agriculture for its economy. But water resources are unevenly distributed across East African countries. As of 2014, two East African countries provided for 100% of their renewable water resource needs internally: Djibouti and Ethiopia. South Sudan relied on neighbouring countries for 65.8% of its water resources in 2014. This is more than double the sub-Saharan African average of 30.4%. Uganda and Kenya are both more dependent on neighbours for a greater share of their water supply than the average sub-Saharan African country, at 35.1% and 32.6% respectively (FAO, 2016a,b cited in USAID, 2017).

The uncertainty in climate projections in East Africa and the large uncertainties associated with hydrological models makes it difficult to predict the precise impacts of climate change on water resources. If there are to be more extended dry spells and a higher proportion of rainfall occurring as intense events, this could have a significant detrimental impact on the reliability of surface water stores, environmental flows, and soil water (Future Climate For Africa, 2016: p.14). This could have important implications for water supply, agriculture, and energy policy and development in a region where terrestrial water stores are already highly spatially variable. More intense rainfall is also likely to lead to an increase in surface flooding, more extreme river flow dynamics, and less predictable surface water stores. Likewise the timing of groundwater recharge, and therefore the seasonal dynamics of groundwater stores, may be altered. This is particularly important in areas with hard rock aquifers which have low storage capacity and which cover much of East Africa (Future Climate for Africa, 2016: p.14). In some regions with relatively low annual average rainfall (less than 1000mm per annum), there is some evidence that more intense rainfall may lead to enhanced recharge of aquifers (Future Climate for Africa, 2016: p.14).

Rising demand poses substantial threats to water security in Sub-Saharan Africa, and this is exacerbated by climatic changes affecting river runoff, contributing to higher irrigation water demand and posing risks of shallow groundwater contamination due to intense rainfall (MacDonald et al. 2009 cited in Serdeczny et al., 2017: 1589). The factors increasing water demand include irrigation and hydropower production, which are both susceptible to an increase in evaporative losses. Seasonal water shortages along river basins are expected mostly in the southern parts of East Africa (Niang et al. 2014 cited in Serdeczny et al., 2017: 1591).

Forestry and ecosystem changes

The East Africa vulnerability, impacts, and adaptation assessment (VIA) was undertaken by the East African Community (EAC) with support from the 'USAID/Kenya and East Africa Planning for Resilience in East Africa through Policy, Adaptation, Research, and Economic Development (PREPARED) Project'. The study adopted the Intergovernmental Panel on Climate Change (IPCC) assessment framework and used locally observed climate data and socioeconomic information for a 30-year period (1981–2010). Detailed analysis for the VIA focused on the Lake Victoria Basin (LVB), the largest water body in the region, which is important to farming, fisheries, transportation, and water supply in the five EAC Partner States included in the VIA (Burundi, Kenya, Rwanda, Tanzania, and Uganda) (EAC, 2018).

Changes in terrestrial ecosystems are already being detected in the EAC region, particularly in the Lake Victoria Basin (LVB). Analysis of satellite-based vegetation imagery from 2001-2009 shows that the area under woody savannah has increased, while natural vegetation - especially forests, shrub lands, and grasslands - has declined in all five East African Partner States. Analysis of rainfall trends between 1984 and 2014 shows that rainfall on the southeastern side of the LVB, which includes the Mara-Serengeti Ecosystem, is more variable compared to other parts of the basin. This could have negative impacts on the growing cycle and alter vegetation cover, which affect wildlife habitat and livestock pasture, leading to increased competition between species (EAC, 2018).

The forests and woodlands of East Africa provide energy, food, timber, and non-timber forest products and contribute to wealth and health at the household, community, national, sub-regional, regional, and even global levels. They harbour rich biodiversity and provide a wide range of ecosystem services. Forests are sources of rivers used to generate electricity in all five EAC countries (Tetra Tech ARD, 2017: p.1). Between 1990 and 2010, Burundi registered the biggest forest losses, followed by Uganda, Tanzania, and Kenya. Only Rwanda registered an increase in forest cover. The impacts of the loss of forests on biodiversity, water, agriculture, and health in the region are enormous and will likely be further amplified by the additional impacts of climate change. Forests are vulnerable to climate change because trees have long lifespans and low capacity to adapt to changing ecological conditions. Climate change will exacerbate the impacts of the processes that already stress and threaten overexploited ecosystems for several reasons, including agricultural expansion, destruction of habitats, pollution, high rates of change in land use, and population growth. Climate change will heighten the impacts of these stressors and will have major effects on both managed and natural ecosystems and associated services (USAID 2013 cited in Tetra Tech ARD, 2017: p.9).

CIFOR (2015) describe AdaptEA, a multidisciplinary study in Uganda and Kenya, which seeks to develop and disseminate policy recommendations and approaches to enhance adaptation of local stakeholders to climate change through sustainable management and use of forests and trees. The four sites are in close proximity to Mount Elgon, a unique provider of forest ecosystem services, representing four different regimes of forest governance and community access, and were studied from 1997-2013. Smallholders in Mount Elgon have identified an increase in the incidence of extreme weather events as well as disturbances in the timing of rainfall, upon which agricultural production systems rely. Many communities have experienced landslides and floods during such extreme weather events. Stakeholders also attribute increased crop pest and disease incidences to changes in rainfall patterns and more extended periods of drought. A detailed household survey in four communities highlighted that these events do not affect all households equally: as access to land, education, availability of livestock and other factors

influence the exposure, sensitivity and adaptive capacity of stakeholders. Community rights of access to forest resources have a significant impact on livelihoods, perceptions of climate change and strategies for coping with climate events. Women's roles in decision-making and alignment with men's perception of climate change were higher in communities that were more reliant on forest resources. The effects of climate change around Mount Elgon are highly variable (especially precipitation changes), but overall it is likely to become warmer. Forest biodiversity is likely to come under pressure with climate change emphasising the need for closer engagement between conservation authorities and communities in the future (CIFOR, 2015).

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