Review of agricultural production systems in eastern Africa in relation to food and nutrition security and climate change

Sarah Hunt[1], Getachew Eshete[1], Million Tadesse[2] and Zewdu Eshetu[3]

[1]Consultant
[2]Holetta Research Center, Ethiopian Institute of Agricultural Research
[3]Addis Ababa University

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Contact:
CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), East Africa. P.O. Box 5689. Addis Ababa, Ethiopia | Phone: +251-11 617 2000 | Fax: +251-11 617 2001 | Email: ccafsea@cgiar.org | Website: http://ccafs.cgiar.org/regions/east-africa

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Contents

Tables 7

Figures 8

Abbrevations and acronyms 10

Acknowledgments 11

Introduction 12

Topical reviews 13

- Agroecological zones 13
- Livestock production systems 15
  - Pastoralism 15
  - Agropastoralism 16
  - Mixed crop-livestock 16
- Food and nutrition security, insecurity and indexes 18
- Climate in East Africa 20
- Climate change in East Africa 21
- Agriculture and livestock production under climate change 22
- Livestock and climate change adaptation 23
- Livestock and greenhouse gas emissions 24
  - Greenhouse gas calculations 26
- Livestock and climate change mitigation 27
- Climate-smart agriculture 30
  - Climate-smart livestock 32

Summaries from the reviewed countries 34

- Livestock production 34
  - Livestock contribution to GDP and livelihoods 34
  - Production systems 35
  - Livestock populations 36
- Food insecurity 38
- Climate change and livestock 39
- Livestock and GHG emissions 39
- Intended Nationally Determined Contributions (INDCs) mitigation and adaptation plans 41
- Climate-smart livestock 43

Conclusions 44

Annex I: Country profiles 46
Eritrea 46
Agricultural production and agroecological zones 46
Food and nutrition security 48
Climate change 49
GHG emissions and livestock 49
Climate-smart livestock 50
Djibouti 52
Agricultural production and agroecological zones 52
Food and nutrition security 54
Climate change 54
GHG emissions and livestock 55
Climate-smart livestock 55
Somalia 58
Introduction: Somalia and Somaliland 58
Agricultural production and agroecological zones 58
Food and nutrition security 61
Climate change 61
GHG emissions and livestock 62
Climate-smart livestock 62
Somaliland 66
Agricultural production and agroecological zones 66
Food and nutrition security 68
Climate change 68
GHG emissions and livestock 68
Climate-smart livestock 69
Ethiopia 71
Agricultural production and agroecological zones 71
Food and nutrition security 75
Climate change 76
GHG emissions and livestock 77
Climate-smart livestock 77
Kenya 81
Agricultural production and agroecological zones 81
Food and nutrition security 84
Climate change 84
GHG emissions and livestock 86
Climate-smart livestock 86
Uganda 90
Agricultural production and agroecological zones 90
Food and nutrition security 95
Climate change 96
GHG emissions and livestock 97
Climate-smart livestock 99

Rwanda ... 104
Agricultural production and agroecological zones ... 104
Food and nutrition security ... 108
Climate change ... 110
GHG emissions and livestock ... 111
Climate-smart livestock ... 112

Tanzania ... 115
Agricultural production and agroecological zones ... 115
Food and nutrition security ... 121
Climate change ... 123
GHG emissions and livestock ... 125
Climate-smart livestock ... 125

Annex II: References and resources ... 129

Thematic resources ... 129
Agroecological zones ... 129
Recent regional livestock overviews ... 129
Older livestock and mixed system reviews ... 129
Livestock studies: Intensification, cultural change, pastoralism ... 130
Livestock trade ... 130
Food, nutrition and security ... 130
Climate change ... 131
Climate and climate change in Africa/East Africa ... 131
Climate change: Food, nutrition and security ... 132
Climate change: Livestock and food, nutrition and security ... 133
Climate change: Livestock systems adaptation and mitigation ... 133
Greenhouse gas emissions and livestock ... 135
Climate-smart agriculture ... 135

Country resources ... 137
Eritrea ... 137
Djibouti ... 138
Somalia ... 139
Somaliland ... 141
Ethiopia ... 142
Kenya ... 146
Uganda ... 148
Rwanda ... 151
Tanzania ... 153

Tables

Table 1: Pastoral groups of East Africa 17
Table 2: Potential impacts of climate change on livestock production separated by direct and indirect effects and highlighting the difference between grazing and non -grazing systems 24
Table 3: Chart showing applications of Tier 2 approaches in national emission reports by livestock type and emission type 28
Table 4: "Most promising mitigation strategies" information from Mottet et al. (2016), generated from their GLEAM analysis of mitigation strategies 29
Table 5: Various strategies for addressing enteric fermentation, manure storage and animal management and their potential for mitigating methane and nitrous oxide 30
Table 6: The role of livestock in GDP and livelihoods, some factoids 35
Table 7: National livestock numbers 38
Table 8: Calculated national densities of ruminants and swine 38
Table 9: Global Hunger Index scores and rankings for the reviewed countries 39
Table 10: PoU as a percentage of the entire population 40
Table 11: Agriculture sector's contribution to the total country GHG 41
Table 12: Estimated GHG emissions with agricultural methane and agricultural nitrous oxide 41
Table 13: Emission rates per capita 42
Table 14: Contribution of selected countries to world emission total 42
Table 15: Potential climate-smart livestock technologies and approaches 44

Appendix

Table 1: Adaptation strategies for the livestock subsector proposed in the 2012 NDC 52
Table 2: Adaptation strategies identified in the 2018 Final NDC 52
Table 3: The eight priority projects set in the Djibouti 2006 NAPA 58
Table 4: Funded adaptation projects for Djibouti with land-based components 58
Table 5: Development Goals for the Livestock sector as listed in the Somaliland Food and Water Security Strategy: Somaliland Vision 2030 71
Table 6: The eighteen multi-sectoral adaptation options identified for National adaptation programmatic initiatives in keeping with developing the Climate Resilient Green Economy 79
Table 7: The ten adaptation strategies proposed for livestock systems in the National CSA planning document 89
Table 8: Proposed actions that promote "synergies in adaptation and mitigation 90
Table 9: The Priority Adaptation Actions for agriculture 101
Table 10: Distribution of cattle types in rural and urban households 109
Table 11: Food insecurity percentages by livelihood zone in 2015 and 2018 110
Table 12: Livestock population numbers for Tanzania in total and disaggregated between the mainland and Zanzibar 121

Figures

Figure 1: AEZ designations can vary depending on the level of differentiation desired or the research question applied 15
Figure 2: Designations of types of agricultural production systems as generated by Otte and Chilonda in their 2003 systematic review 18
Figure 3: Livestock production systems in the IGAD region. 19
Figure 4: Cropping and pastoral systems in East Africa can have a unimodal or a bimodal distribution, with the timing of the outset and duration of rainfall having direct effect on plant propagation and growth. Even if total rainfall meets yearly averages, the distribution of that rain over the yearly cycle is critical to both crop and livestock production systems 22
Figure 5: Impact of climate change on livestock from increase in CO2, increase in temperature and precipitation variation 24
Figure 6: Impact of livestock on climate change, diagram representing the different sources of gas release in livestock production 25
Figure 7: Diagram showing the contribution of livestock to the global GHG emissions 26
Figure 8: GHG emissions in the global livestock supply chain by emissions category 27
Figure 9: Main livestock prodution systems across Africa 37
Figure 10: Livestock production levels 38

Annex 1

Figure 1a: Four agroecological zones denominated 48
Figure 1b: Six agroecological zones delimited 48
Figure 2: Livelihood zones of Djibouti 53
Figure 3: Map showing the division of Somalia and Somaliland 59
Figure 4: Somalia can be divided into 32 agroecological zones 60
Figure 5: Livelihood zones map 60
Figure 6: Proposed adaptation measures for livestock systems in the 2013 National Adaptation Programme of Action to Climate Change 65
Figure 7a: Map of Somaliland agroecological zones 67
Figure 7b: Map of Somaliland livelihood zones 68
Figure 8: Agricultural production systems as classified by FAO 72
Figure 9: Agroecological zone classification with 18 regions 72
Figure 10a: Eight agroecological zones 73
Figure 10b: Sixteen Farming Systems 73
Figure 11a and 11b: Livestock production systems a, and subsystems b 75
Figure 11c: Percentage distribution of livestock by the four-production zones 75
Figure 12a: Agro-climatic zone map for Kenya from 1980, by the Ministry of Agriculture Kenya Soil Survey 82
Figure 12b: Agroecological zones map from the 2010 State of the Environment report 82
Figure 12c: The landscape of Kenya classified by potential for agriculture 82
Figure 13a: Generalized 2010 livelihood zone map from FEWSNET 83
Figure 13b: Detailed agro-climatic zones map for Kenya 83
Figure 13c: Kenya agricultural production zones by commodity crops, annual crops and forest reserves 83
Figure 14: Herd and Flock size for Kenya in 2015 84
Figure 15: Precipitation changes in Kenya under four different models 86

Figure 16: Map showing the distribution of the various dairy production systems 88
Figure 18: The aggregated map of 14 zones that is more frequently used 92
Figure 19: Ugandan ten production zone map as developed by MAAIF in 2004 92
Figure 20: MAAIF ten production zone map with major agricultural sector production shown 93
Figure 21: Livelihood zone map with 38 zones, which was collaboratively produced by government and NGO workers under FEWS NET leadership 93
Figure 22: Percentage of household that own cattle by district 95
Figure 23: Four different future scenarios for average precipitation for Uganda based on different Global Circulation Models 97
Figure 24: Emissions by production systems 99
Figure 25: Emissions intensities by production system 99
Figure 26: Total GHG emissions per region from the dairy production sector in Uganda 103
Figure 27: Physical landscape of Rwanda, demonstrating the east to west differentiation of the landforms 105
Figure 28: 10 Agroecological zone 106
Figure 29: Reclassified land use map generated through Rwandan resource mapping workshop in 2010 106
Figure 30: Rwandan livelihood zones, FEWS NET developed zone map from 2012 107
Figure 31: Rainfall distribution for Rwanda 111
Figure 32: Emissions under planned mitigation scenarios for Rwanda 114
Figure 33: Original agroecological zonation of Tanzania 116
Figure 34: Simplified agroecological zonation, condensed to ten zones 117
Figure 35: Livelihood map developed by FEWSNET and the Tanzanian Food Security Information Team 117
Figure 36: Condensed livelihood zone map 118
Figure 37: Contributions of the subsectors to the total agricultural GDP 119
Figure 38: Simplified agroecological zone and livestock production practices 120
Figure 39: Figure Regional food insecurity vulnerability 123
Figure 40: The food insecurity map developed from the 2017 national comprehensive food security and nutrition assessment report 123
Figure 41: Four downscaled general circulation models showing change in mean annual precipitation up to 2050 125

Abbreviations and acronyms

AEZ	Agroecological zone
ASAL	Arid and emi-arid land
CIP	Crop Intensification Program
CRGE	Climate resilient green economy
CSA	Climate-smart agriculture
DJF	Djiboutian Franc
ENSO	El Niño southern oscillation
FAO	Food and Agricultural Organization of the United Nations
GDP	Gross domestic product
GHA	Greater Horn of Africa
GHG	Greenhouse gas
GHI	Global hunger index
GLEAM	Global Livestock Environmental Assessment Model
ICPAC	IGAD Climate Prediction and Applications Centre
ICPALD	IGAD Centre For Pastoral Areas and Livestock Development
IDP	Internally displaced person
IFAD	International Fund for Agricultural Development
IGAD	Intergovernmental Authority for Development
IMF	International Monetary Fund
INDC	Intended nationally determined contribution
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical convergence zone
LDC	Least developed country
LPST	Livestock production system transitions
LULUCF	Land Use, Land Use Change and Forestry
MRV	Monitoring, reporting and verification
NAMA	Nationally appropriate mitigation action
NAP	National adaptation plan
NAPA	National Adaptation Program of Action
NDC	Nationally determined contribution
NGO	Non-governmental organization
PoU	Prevalence of undernourishment
SNC	Second national communication
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WB	World Bank
WFP	World Food Programme
WRI	World Resources Institute

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Introduction

The goal of this paper is to provide a unified resource for Eritrea, Djibouti, Somaliland, Somalia, Ethiopia, Kenya, Uganda, Rwanda and Tanzania. For each country the review covers the topics of livestock production systems and agroecological zones, food and nutrition security, climate change, greenhouse gas (GHG) emissions and climate-smart agriculture (CSA) with a focus on the role of, or impact on, livestock systems. Each of these topics is broad and many excellent studies and reviews have been produced covering these topics either at the country level or for the entire East Africa region. It is the goal of this paper to provide an accessible introduction to these topics and to direct readers to the resources that exist for gathering detailed information on livestock production, food nutrition and security, climate change, GHG emissions and climate-smart livestock production in each country.

This paper first provides overviews of the topical categories as well as summaries from the reviewed countries, followed by profiles for each of the nine countries. Key country specific resources for each topic are listed in each country profile. At the end of the report there is a resource section that is organized by topic themes where overviews and regional reports are listed. There is then a resource for each country providing references and links to recent research, international organizations and governmental papers related to livestock and the reviewed themes. This resource is not exhaustive of all the available studies on a country, but rather is a focused review of key livestock and livestock systems literature.

Topical reviews

Agroecological zones

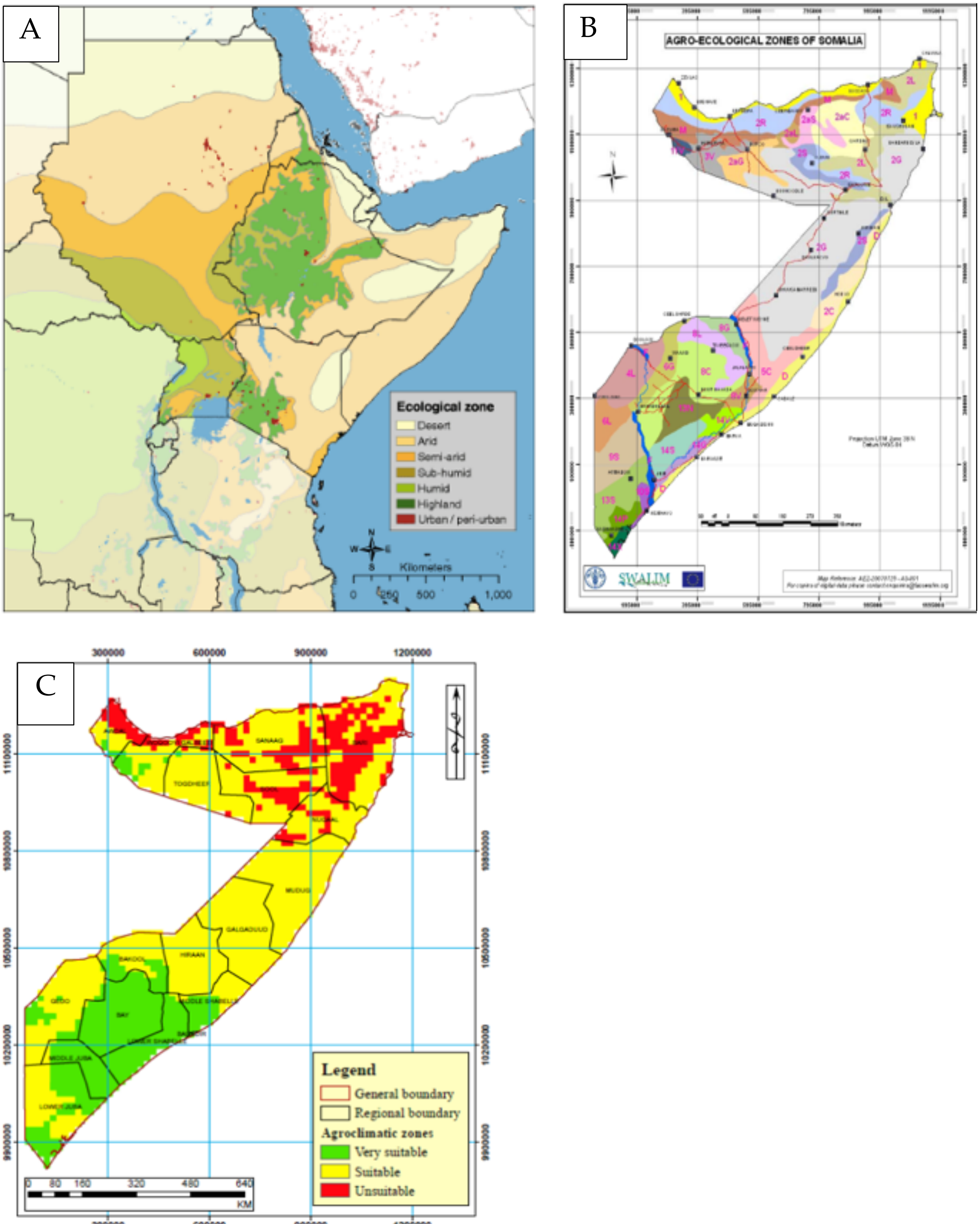
Landscapes can be described and delimited by many different parameters, from physical traits (topography, precipitation, soil types), to ecological traits (plant life, growing seasons), to social traits (livelihoods, population densities, ethnic composition, political borders). Within the development and agronomic research sectors the landscape descriptor of agroecological zone (AEZ) has become recognized. Designation of AEZs utilizes a combination of biophysical characteristics (rainfall, topography, growing season and soil type) to help classify landscapes into their current and potential agricultural production uses. The development of this framework is credited to the Food and Agriculture Organization of the United Nations (FAO) (Fischer et al. 2000).

Initial AEZ designations were not exceptionally fine grained. For example, in the early 1990s, AEZ designations for all Sub-Saharan Africa were just five types; arid, semi-arid, sub-humid, humid and highland (Winrock International 1992; McIntire et al. 1992). Such coarse grain designations continue to be used, especially when researchers are attempting to analyze expansive regions (see for example Otte and Chilonda's 2003 livestock review of Sub-Saharan Africa, or Knips 2004 report on the livestock sector of the Horn of Africa).

However, with further development of geographic information systems (GIS) mapping through increases in data available from satellites, remote sensing and increased computational powers, AEZ designations can become very fine grained. This can make comparisons between countries or even between research projects difficult. Take for example three different representations of Somalia (Figure 1). In Figure 1a, the majority of Somalia is simply arid, with a bit of desert and highland in Somaliland. But Somalia has also been differentiated into 32 different zones in a fine-grained FAO analysis (Figure 1b). However, advancements in data richness does not necessitate this fine-grained differentiation. Utilizing similar soil, rainfall and topography GIS data for Somalia, Boitt et al. (2018) chose a coarser grain for their output which focused on agricultural suitability (Figure 1c).

In the country profiles below, differences in AEZ designations will be discussed as necessary and links to key map resources will be provided.

Figure 1: AEZ designations can vary depending on the level of differentiation desired or the research question applied. (A)Knips 2004; (B) Venema 2007; (C) Boitt 2018.



Livestock production systems

Classification of agricultural production systems or livelihood strategies varies widely (see Robinson et al. 2011 for a review of different typologies for global livestock systems). The types of factors that are used to designate systems are many and the terminological preferences can vary between research disciplines, international organizations and governments.

The axes of differentiation include many non-exclusive factors, for example:

- Economic orientation: subsistence, cash crop, commercial;
- Household movement: sedentary, semi nomadic, nomadic;
- Method of feeding: free grazing, pasturage, tethering, stall-feeding, zero-grazing;
- Size of the landholdings: relative scales (small, medium, large), actual acreage;
- Landholding structure: private, group ranches, communal, insecure tenure;
- Livestock holdings: smallholders, ranches, industrial;
- Type of animals: dairy production, beef production, small ruminants, poultry, apiculture;
- Type of crops: annual, perennial, horticulture, market gardens, commodity production;
- Location regarding human population density: rural, peri-urban, urban;
- Location regarding landscape: coastal, lowlands, highlands, riverine, montane type of land management: rain fed, irrigation, crop rotation, permanent pasture, rotational grazing, transhumance;
- Degree of intensification: extensive, intensive;
- Relative importance of livestock: pastoralism, agropastoralism, mixed crop-livestock.

Within livestock research and development in African systems, the tripartite classification of pastoral, agropastoral and mixed crop-livestock has become frequently used as it links the system of livestock production to agriculture, overall household livelihood strategies and groups households into units that seem functionally similar. The three production systems are roughly differentiated as pastoralism, agropastoralism and mixed crop-livestock.

Pastoralism

Pastoral livelihoods rely on livestock which are moved across a wide landscape in search of water and grazing. Pastoral practices are further subdivided into true nomadic, with no set pathways, or transhumance wherein seasonally determined movement patterns are followed on a yearly basis. Movement of the animals can be to find fresh pasture, to access seasonally available water, to avoid seasonal pests and diseases, or to attend market events. Within pastoral communities, various types of household arrangements can occur. Sometimes the movement across the landscape is enacted by the entire household and herd, whereas at other times the household and herd might be split. Often women and children stay in temporary camps with part of the herd near particular resources (historically good water and pasture sites to maintain the young and lactating animals, now key resources include schools, health clinics and formalized markets), while youth and men take the rest of the herd to other pasturage. Throughout the world, pastoralism is closely tied to ethnic identities and this is true for East Africa as well (Table 1). This is salient because animal ownership and the nomadic practices of pastoralism in themselves have important social functions and can be cornerstones of emotional wellbeing and social identity. These ethnic relations and transhumant pathways cross landscapes that are now divided by national borders. For many reasons, there is a worldwide trend toward sedentarization of historically nomadic and transhumant ethnic pastoral peoples.

Table 1: Pastoral groups of East Africa. Table from Blench 2001.

Language Phylum	Language Branch	Language	Group	Location	Main Pastoral Species
Afroasiatic	Omotic	Hamar	Hamar	S. W. Ethiopia	Cattle, sheep, goats
	Cushitic	Somali	Somali	Somalia	Camels
	Cushitic	Afar	Afar	Somalia/Djibouti	Camels
	Cushitic	Borana	Borana	Ethiopia/Kenya	Cattle, sheep, goats
	Cushitic	Rendille	Rendille	Kenya	Camels, sheep, goats
	Cushitic	Gabra	Gabra	Kenya	Camels
Nilo-Saharan	E. Sudanic Nilotic	Maa	Maasai	Kenya/Tanzania	Cattle
	E. Sudanic Nilotic	Il-Camus	Samburu	N. Kenya	Cattle
	E. Sudanic Nilotic	Turkana	Turkana	N. Kenya	Cattle
	E. Sudanic Nilotic	Karimojong	Karimojong	N.E. Uganda	Cattle
	E. Sudanic Nilotic	Jie	Jie	N.E. Uganda	Cattle
	E. Sudanic Nilotic	Anywak	Anywak	S. Sudan/Ethiopia	Cattle

Agropastoralism

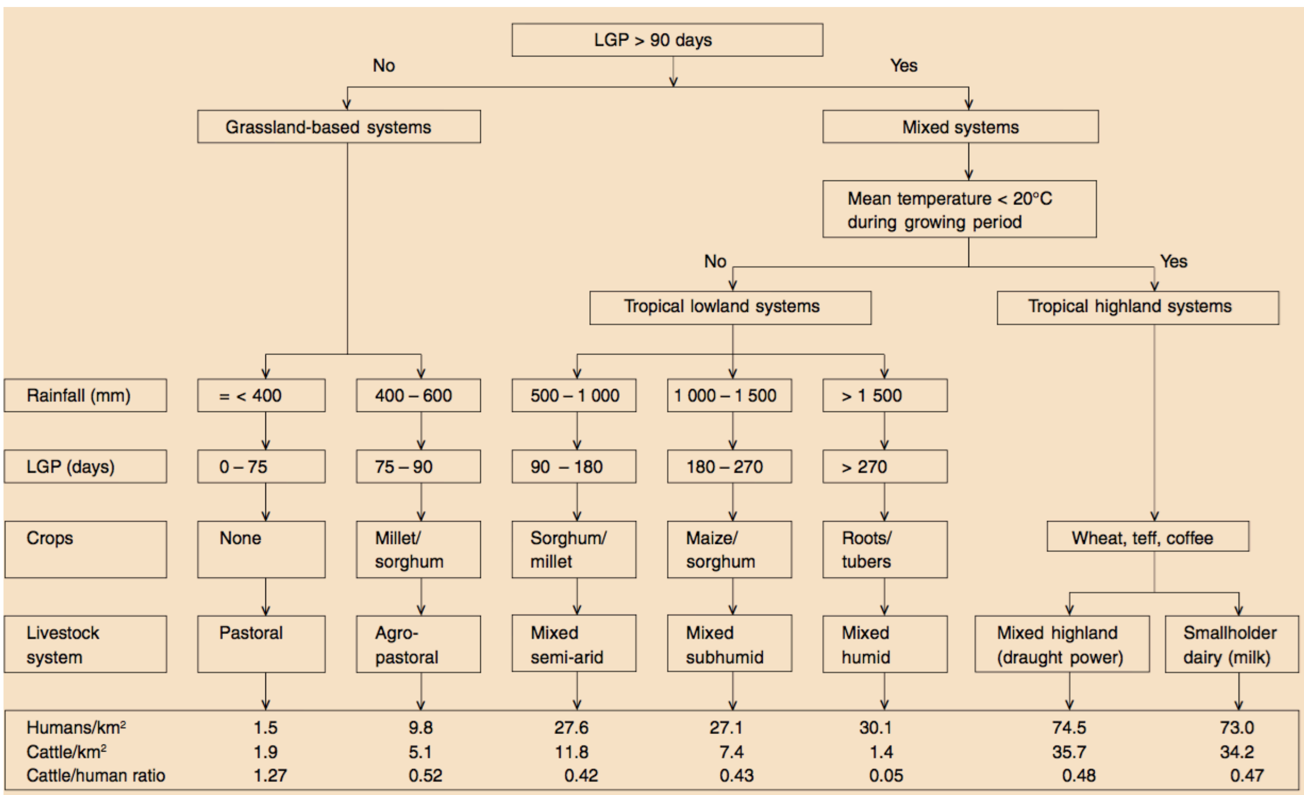
Agropastoral households rely on both pastoral methods of livestock keeping and some degree of crop production. Within this broad category, two main differentiations should be noted. Some agropastoral peoples are predominately, or ethnically, more closely allied with pastoralism and practice only a small amount of agriculture. Though pastoral peoples might have historically done crop production at temporary camps, as pastoral people become sedentary, crop production can provide more of the household economy such that they become classified as agropastoralists. Agropastoralism is also practiced by historically farming people who also maintain animals. These herds can be kept at the farm or sent out for free grazing (at times herded by hired pastoral people). Livestock herd composition can be different between pastoral and agropastoral systems in the same landscape, most notably that agropastoral households are noted for keeping cattle for on-farm traction and transportation purposes. For both pastoral and agropastoral production small ruminants are often the dominant animal in number. In agropastoral and mixed-crop livestock systems crop residues can be an element of the livestock feeding practices.

Mixed crop-livestock

The differentiation between mixed systems and agropastoral systems is on the degree to which livestock contributes to the household economy, as well as on the main methods of livestock feeding. Mixed systems, in general, are seen as predominately crop production livelihoods wherein the livestock are supplementary to the crop production. Animals provide important inputs to the crop production in the form of on farm labour (traction and carting) and manure as organic fertilizer. Livestock are more often fed through grazing on crop residues, tethering or stall feeding rather than through extensive grazing.

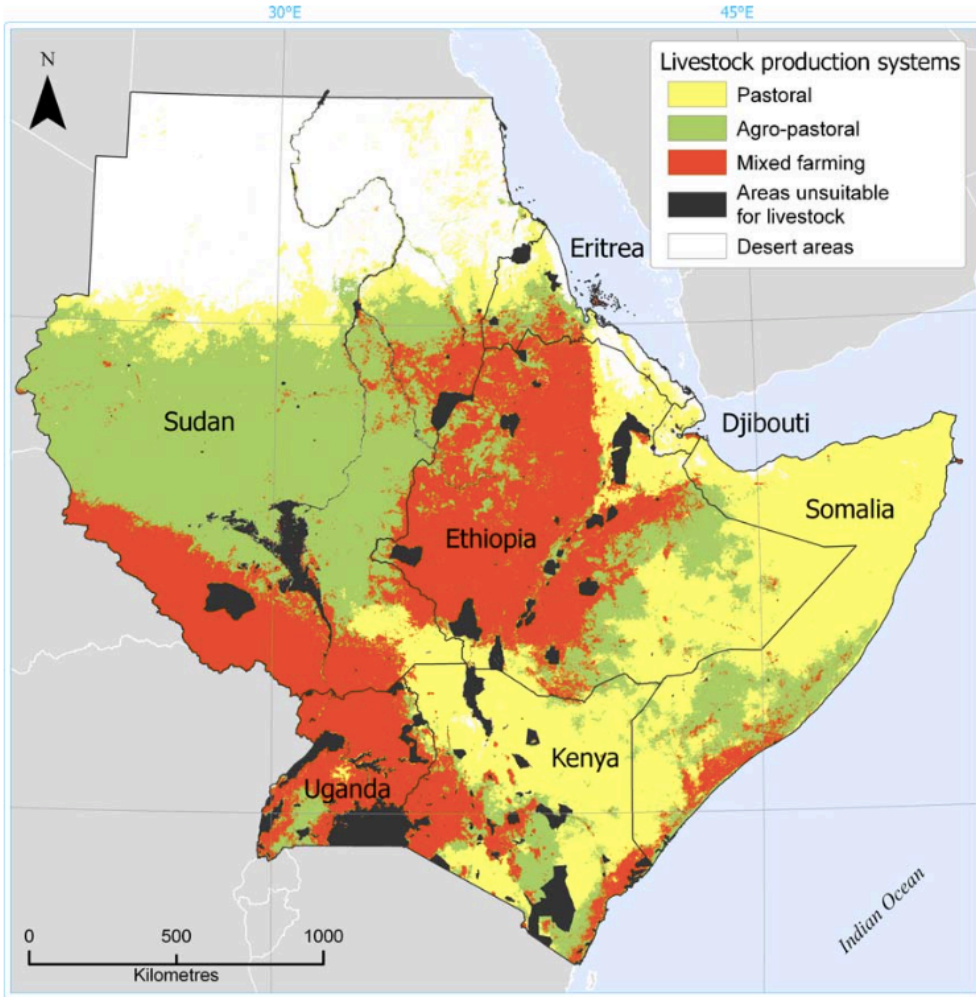
A systematic review of livestock production systems in Sub-Saharan Africa was conducted in 2003 by Otte and Chilonda, which further portioned these three broad categories into sub units as related to the AEZs. Their review showed that pastoral and agropastoral systems correlate highly with rainfall and growing periods that denote grassland dominated ecosystems. With more rainfall and lower temperatures, various types of mixed systems are found (Figure 2). Otte and Chilonda (2003) further point out that the relative degree of importance of livestock versus crops in the different systems can vary even in systems designated by the same name. In general, they found that pastoral systems have more than 50% of the economic livelihood coming from livestock. In mixed crop-livestock at least 50% of income comes from crops. In all designations it is important to consider not just the cash income from market materials, but also to include an estimated value from subsistence production.

Figure 2: Designations of types of agricultural production systems as generated by Otte and Chilonda in their 2003 systematic review.



A more recent study of the East African systems has more strictly defined the three production systems on the ratio of the household economic value of livestock (L) to crops (C). The three production systems are designated as pastoral: L/C ≥ 4; agropastoral: 1<L/C<4; and mixed farming as L/C≤1. To accommodate the mixed systems of urban and peri-urban areas where crops and livestock can contribute only a small fraction of household economy (less than 10%), they designated a fourth category of "urban and other" (Cecchi et al. 2010). In this review the authors utilized known regional livelihood data as well as a model livestock production system through climatic and ecological zones for the the Intergovernmental Authority for Develoment (IGAD) (Figure 3).

Figure 3: Livestock production systems in the IGAD region (Cecchi et al. 2010)



Overall, the methodological choice of designation of production zones and the degree to which they are finely differentiated has much to do with the research or policy questions that have driven the study or analysis. In the country profiles in Annex I, research on the production zones and types for each country will be discussed with an emphasis on the livestock aspects of the agricultural production systems and resources provided for access to recent country overviews.

Food and nutrition security, insecurity and indexes

Food security has had many different definitions over time, but since the World Food Summit in 1996 a standard definition has begun to dominate the food and nutrition sector which is:

> Food security is when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. (FAO 1996).

From this, food insecurity becomes conceptualized as ‘a situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life’ (FAO 2013). Food security and insecurity are operationalized along the four pillars of accessibility, availability, utilization and stability[1]. In the 2019 Food Security and Nutrition in the World review, food insecurity is further delimited into acute versus chronic food insecurity. Acute insecurity is a condition that occurs at a specific place and time and which could be addressed with short-term aid or management to mitigate the food insecurity which threatens lives and livelihoods (for example location-specific feeding stations and veterinary support to drought afflicted pastoral communities). Chronic food insecurity persists over time and is conceptually linked to more structural causes. Chronic food insecurity includes the yearly seasonal shortfalls that can occur for subsistence agricultural and pastoral production even in normal years, as well as the nutritional deficits that can occur in the calorically sufficient, but limited diversity diets, that are common with cereal dependent smallholder subsistence households (Mohamed 2017).

Food insecurity and nutritional deficits can vary spatially and temporally within communities and even within individual households making it a difficult concept to operationalize and measure. Many different parameters and indexes exist for classifying populations and nations in relation to their overall food and nutrition statuses and security. Models have moved away from relying heavily on economic or poverty measures, because wealth measures are not a sufficient indicator of food security (Ryan and Leibbrandt 2015). Many comprehensive food security indexes have been proposed by academic researchers (see Food Insecurity Multidimensional Index in Napoli 2011), by agribusinesses (see Global Food Security Index in Economist 2018) and by international food and relief institutes (see Global Hunger Index in Wiesmann et al. 2015 and Prevalence of Undernourishment (PoU) in Wanner et al. 2014). All these indexes agree that food or nutrition security is a multi-factor concept, but there is still much debate and research about which indicators are the most salient (Napoli 2011; Maxwell et al. 2013; Ryan and Leibbrandt 2015; Mohamed 2017; Haug 2018 for analytical reviews of the value of different indicators in food security and insecurity indexes).

In short, countries and organizations use a variety of measurable indicators to make determinations of food insecurity or undernourishment in a region. Some of the most frequently cited indicators are measures done on children under five years of age; these are underweight (low weight for age), stunting (low height for age) and wasting (low weight for height). The International Food and Policy Research Institute (IFPRI) uses the Global Hunger Index (GHI), which is comprised of three components: inadequate food supply, child mortality and child undernutrition. FAO and WFP widely use PoU, which

[1] Availability: This dimension addresses whether or not food is actually or potentially physically present, including aspects of production, food reserves, markets and transportation, and wild foods. Access: If food is actually or potentially physically present, the next question is whether or not households and individuals have sufficient access to that food. Utilization: If food is available and households have adequate access to it, the next question is whether or not households are maximizing the consumption of adequate nutrition and energy. Stability: If the dimensions of availability, access and utilization are sufficiently met, stability is the condition in which the whole system is stable, thus ensuring that households are food secure at all times. Stability issues can refer to short-term instability (which can lead to acute food insecurity) or medium- to long-term instability (which can lead to chronic food insecurity). Climatic, economic, social and political factors can all be a source of instability (FAO 2018).

measures the proportion of a population that lacks sufficient caloric input to meet the minimum energy requirements of that population.

In the country reviews in Annex I, various indicators and indexes are cited as found within the literature for each country. Recent world hunger and food insecurity reviews (von Grebmer et al. 2018; FAO et al. 2019) provide cross region data, which will be discussed in the regional review at the end of the report.

Climate in East Africa

The climate of the reviewed countries varies widely from arid lowlands to humid tropical montane regions (see Chamberlin (2018) for a detailed review of existing climate knowledge of the East African region). For most of the reviewed countries two major planetary climatic events, the Intertropical Convergence Zone, the El Niño Southern Oscillation and the Indian Ocean Dipole have important roles in inter-annual variability in rainfall.

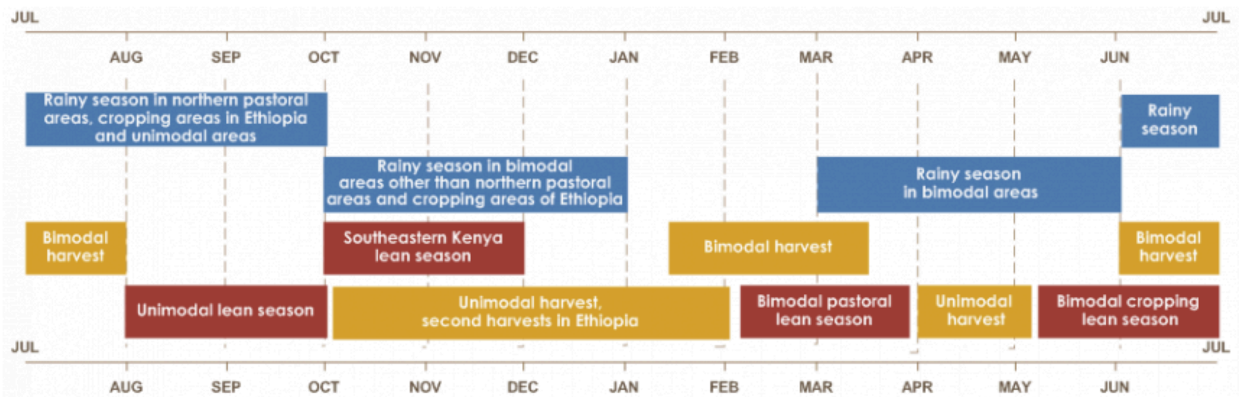
El Niño Southern Oscillation (ENSO): El Niño references periods of above normal sea surface temperatures in the tropical Pacific Ocean. The southern oscillation is the shift in the atmospheric pressure and prevailing winds across the Pacific. Together these Pacific Ocean events shift weather patterns around the globe. El Niño contributes to drought conditions in East Africa (Funk et al. 2016).

The Indian Ocean Dipole: Follows the same principle as ENSO in the Pacific Ocean for the Indian Ocean.

Intertropical Convergence Zone (ITCZ): The ITCZ is a low pressure belt that forms between the northern and southern hemispheres at the intersection of the trade winds. The ITCZ shifts north and south around the equator in yearly seasonal cycles from variations in mean solar radiation due to the earth's axial tilt. However, though seasonally predictable, the degree of divergence of the ITCZ is affected by other global atmospheric events and local oceanic temperatures. Therefore, ITCZ driven rainfall patterns are subject to perturbation by global climate conditions like El Niño, though the degree of correlation is still being researched (Funk et al. 2016; Liebmann et al. 2014). With the rising local Indian Ocean temperatures and more frequent El Niño events, interannual variability in the ITCZ divergence is predicted to increase (Koech 2015).

Though the ITCZ is a predictable seasonal atmospheric event, regional topography greatly effects the rainfall outcomes of the ITCZ divergence (Koech 2015). Subsequent differences between lowlands and highland rainfall patterns means that countries can have both unimodal and bimodal cropping patterns across their territory (Figure 4). The inland portion of East Africa also has climatic influences from the "inland sea" of Lake Victoria which creates a lake affected weather patterns in western Kenya, Uganda and Tanzania.

Figure 4: Cropping and pastoral systems in East Africa can have a unimodal or a bimodal distribution, with the timing of the outset and duration of rainfall having direct effect on plant propagation and growth. Even if total rainfall meets yearly averages, the distribution of that rain over the yearly cycle is critical to both crop and livestock production systems. Image from FEWS NET East Africa 2019 at https://fews.net/east-africa/food-security-outlook/july-2019.



Climate change in East Africa

Analysis of past meteorological data for the region has found clear signals for overall warming but lacks clear outcomes in regard to rainfall patterns (Omondi et al. 2013; Ghebrezgabher et al. 2016). Similarly, though there is general agreement across climate models for increasing temperatures in East Africa, these models have less consistency for rainfall predictions across the region. One reason for variation in predictions is because climate models poorly map the movement of the ITCZ divergence and subsequent rainfall predictions are of low quality in regions with high ITCZ dependent rainfall (Christensen et al. 2007). Changes in sea surface temperatures (both in the Indian and the Pacific Ocean) are shown to have high correlations with rainfall and interannual variability in the end of the year rains (October to December) but to have less influence on March through May rains (Liebmann et al. 2014). Though earlier models, including the Intergovernmental Panel on Climate Change (IPCC) 2007 report, indicated a wetter trend for the Greater Horn of Africa (GHA) in the future, while more recent modelling calls this possibility into question (Tierney et al. 2015).

Modelling of future rainfall for East Africa under the CMIP3 model found trends toward increased end of year rainfall driven by ENSO and local Indian Ocean modality; these year end rains are predicted to produce the majority of overall future gains in precipitation (Shongwe et al. 2011). Thus, though areas of East Africa are predicted to get wetter under climate change, these increases are coupled to increases in heavy or extreme precipitation events in parts of the year, with potential decreases in other seasons. Increases in the short rains at the end of the year may not offset the decreases in the traditional "long rains" and overall climate changes (increases in CO_2 concentrations and higher temperatures) can increase the speed and intensity of drying during the dry seasons. It is this intra-annual variability which leads many climate change models to include forecasts for increased likelihood of both floods and droughts. Further modeling and region specific analysis needs to be done to clarify the potential changes in the GHA (Tierney et al. 2015) and trends in future water availability for crops and livestock need detailed assessment (Shongwe et al. 2011).

In the country reports in Annex I, distinct country level findings will be presented where possible and links to detailed country reviews will be provided.

Agriculture and livestock production under climate change

With increased temperatures and changed precipitation patterns, agricultural production zones are predicted to shift worldwide. In East Africa crop yields can decrease or increase depending on the crop and region (Ramirez-Villegas and Thornton 2015) and the specificity of these changes highlights the need for local and context specific adaptation plans (Thornton et al. 2007). Climate change impacts on crop production can include changes in planting times, growing season length and local shifts in viable crop types or cultivars as temperature and rainfall patterns change. Though rainfall patterns might shift potential growing areas in East Africa, even bringing new land under cultivation, overall crop production can be decreased by heat stress (Lobell 2011a). For overviews of worldwide agriculture and food security issues see The Future of Food and Agriculture (FAO 2017a). For detailed reviews of the East African region and country specific mapping of potential agricultural crop shifts and subsequent outcomes for food and nutrition security see both the Greater Horn of Africa Climate Risk and Food Security Atlas[2] (ICPAC and WFP 2018a) and East African Agriculture and Climate Change: A comprehensive analysis[3] (Waithaka et al. 2013).

Potential impacts of climate change on livestock can be either direct or indirect effects (Table 2) and result from increased CO_2, increased temperatures and variation in precipitation (Figure 5). Forage and fodder availability can change both through the drying of landscapes as well as general plant community changes due to increased CO_2 and variable weather conditions. Changes in temperature can negatively affect livestock health through heat stress, variation in disease risk and insect vector spread (for reviews, see Kimaro and Chibinga 2013; Grace et al. 2015; Bett et al. 2017). Overall animal life cycle changes from fodder and temperature stress can include breeding patterns, parturition dates, growth patterns and milk and meat production capacities. Forage and water shortages can lead to significant livestock death with subsequent losses of genetic resources. Researchers have noted that livestock systems have been less studied in relationship to climate change than have crop systems; but that is changing. For recent comprehensive reviews of climate change and livestock see Rojas-Downing et al. 2017 and Escarcha et al. 2018. For a focused review on Africa and livestock see Thornton et al. 2015. The above mentioned ICPAC and WFP 2018 Climate Risk and Food Security Atlas includes reviews of livestock production as well.

In the country reports in Annex I distinct country level findings will be presented where possible and links to detailed country reviews will be provided.

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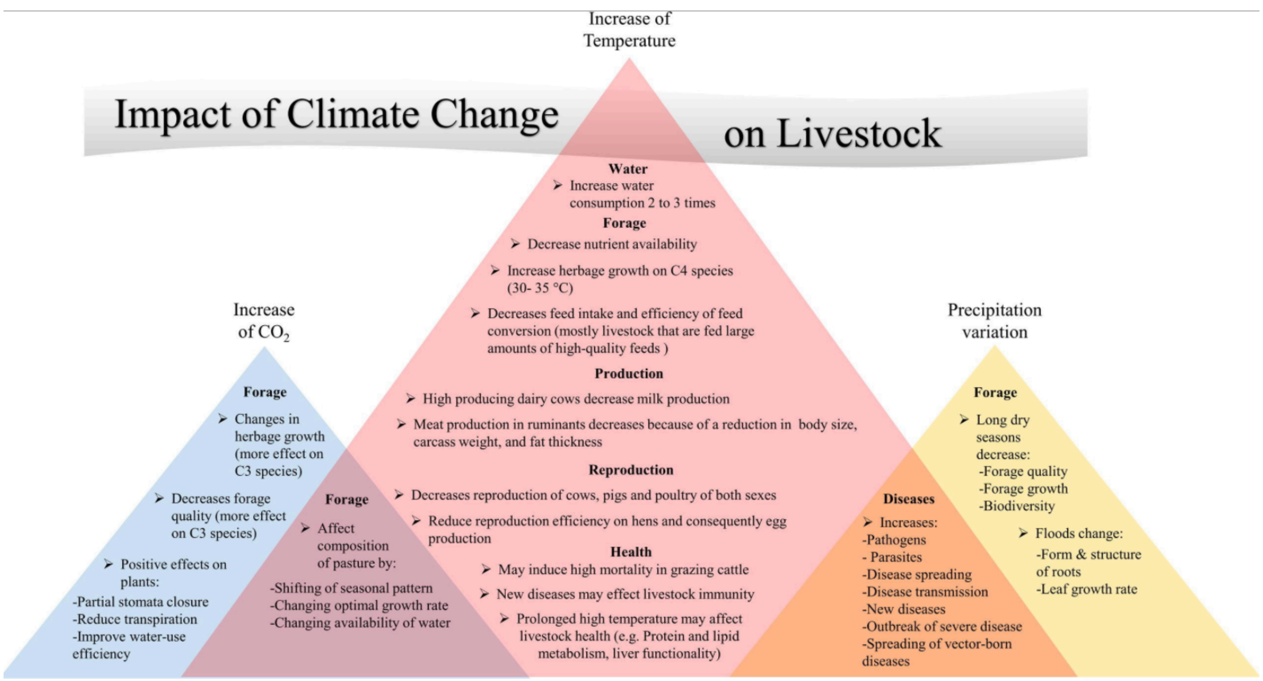
[2] This Atlas has detailed chapters for Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, South Sudan, Tanzania and Uganda.

[3] This regional review has detailed chapters for Burundi, Democratic Republic of Congo, Eritrea, Ethiopia, Kenya, Madagascar, Rwanda, Sudan, Tanzania and Uganda.

Table 2: Potential impacts of climate change on livestock production separated by direct and indirect effects and highlighting the difference between grazing and non grazing systems. Chart information from Thornton et al. 2015.

	Grazing systems	Non grazing systems
Direct impacts	Extreme weather events	Extreme weather events
	Water availability	Water availability
	Drought and floods	
	Productivity losses (physiological stress) owing to temperature increase	
Indirect impacts	Fodder quantity and quality	Increased resource price, e.g. feed and energy
	Disease epidemics	Disease epidemics
	Host-pathogen interactions	Increased cost of animal housing, e.g. cooling systems

Figure 5: Impact of climate change on livestock from increase in CO_2, temperature and precipitation variation. Image from Climate and Livestock review by Rojas-Downing et al. (2017).



Livestock and climate change adaptation

Faced with the uncertainties of climate change and the potential impacts on crop and livestock productivity, it is widely accepted at national and international levels that agricultural production systems need to adapt. Adaptation strategies aim to reduce farmer and livestock holder risk to productivity losses under climate change as well as to make production systems resilient to climate shocks in an uncertain future. Adaptation is a broad concept and can involve ‘production and management system modifications, breeding strategies, institutional and policy changes, science and technology advances, and changing farmers’ perception and adaptive capacity’ (Rojas-Downing et al. 2017).

Adaptation possibilities vary across production systems, but a systematic review of climate change and adaptation in livestock systems found that 'the documented adaptation responses are mostly incremental through management and technology adjustments to reduce the impacts, and less on systemic measures such as institutional and policy changes' (Escarcha et al. 2018). Within the East African research and development context much emphasis is placed on mixed crop and livestock systems. These systems are already highly prevalent in the East African context and these mixed systems are seen as having many synergistic aspects that make them likely targets for improving productive capabilities as well as adapting them to be resilient in the face of climate change (IFAD 2013, on the value of smallholders in food security; Descheemaeker et al. 2016 and Duncan et al. 2014 on adaptive potential in mixed crop-livestock systems). Extensive pastoralism is seen as being very vulnerable to climate change and often construed as having few adaptation options. Escarcha et al. (2018) note that 'leaving pastoralism altogether' is one of the reviewed adaptation techniques for pastoral systems in Africa. However other scholars are less pessimistic, pointing out that pastoral systems through their mobility are already adapted to utilizing resources that have high spatial and temporal variability (FAO and IFAD 2016). In some contexts, pastoralism could be the only productivity system that makes sense on expanding drylands (Nori et al. 2008).

See below in climate-smart agriculture for further discussion of adaptation technologies and opportunities in East Africa.

Livestock and greenhouse gas emissions

Livestock not only are impacted by climate change, but they are also major contributors to climate change through GHG emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (Figure 6). A global review of livestock greenhouse gas (GHG) emissions (Gerber et al. 2013a) concluded that livestock account for 14.5% of anthropocentric GHGs and that these emissions are mainly in the form of methane and nitrous oxide (Figure 7). This is significant because CH_4 and N_2O have much higher warming potentials than CO_2.

Figure 6: Impact of livestock on climate change, diagram representing the different sources of gas release in livestock production. Graphic from Rojas-Downing et al. (2017).

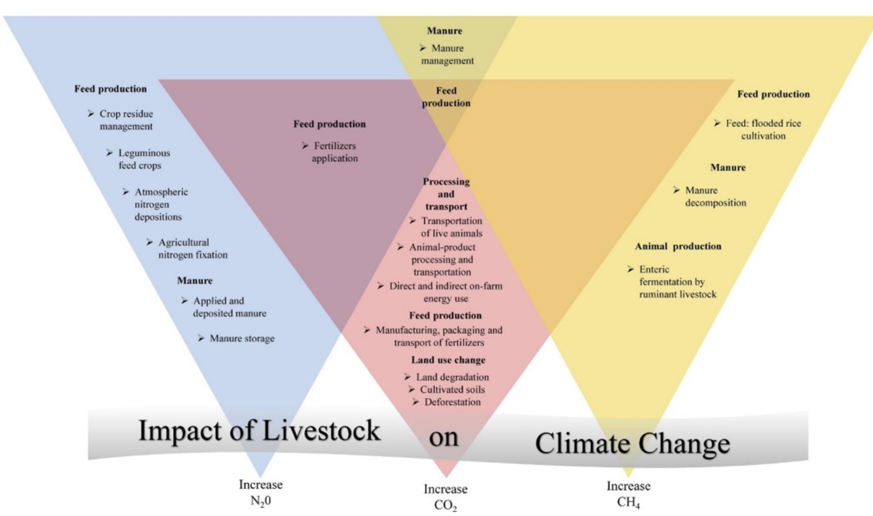
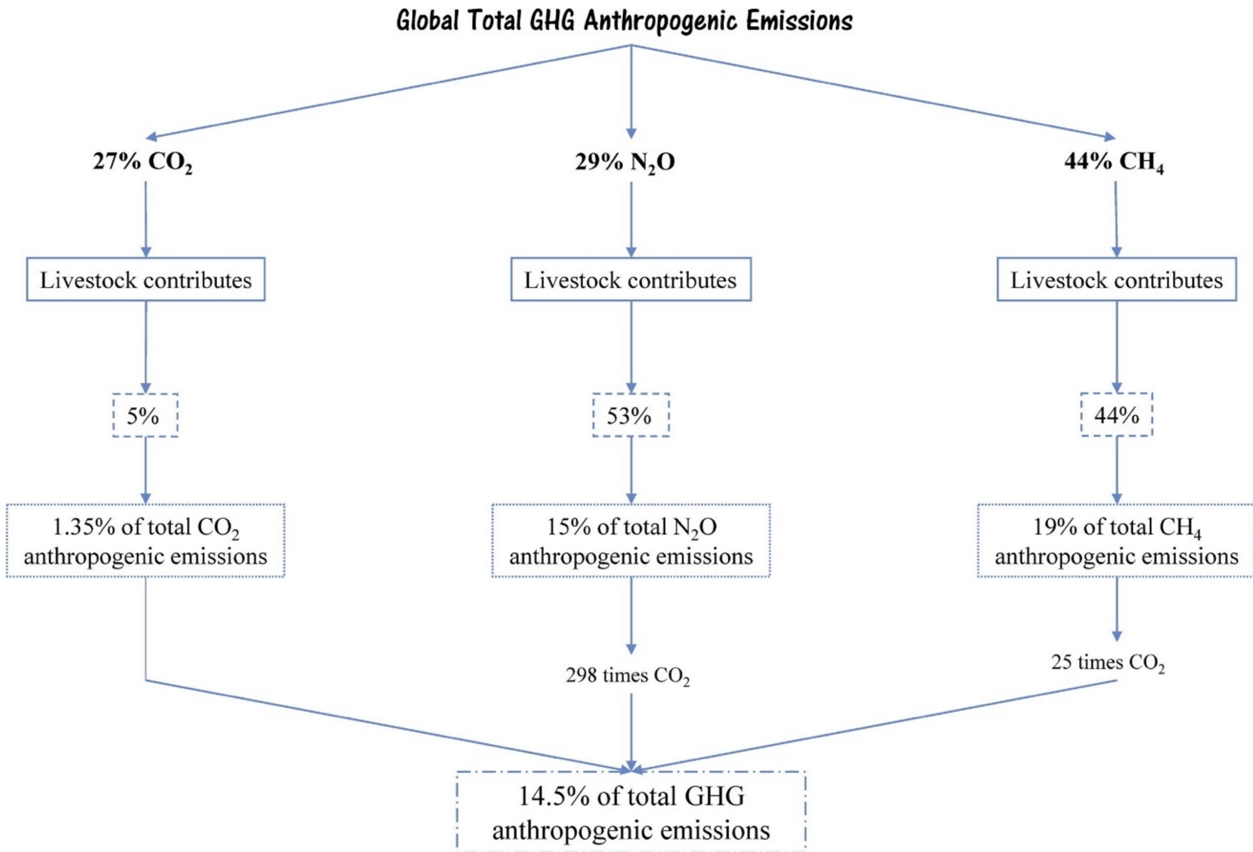
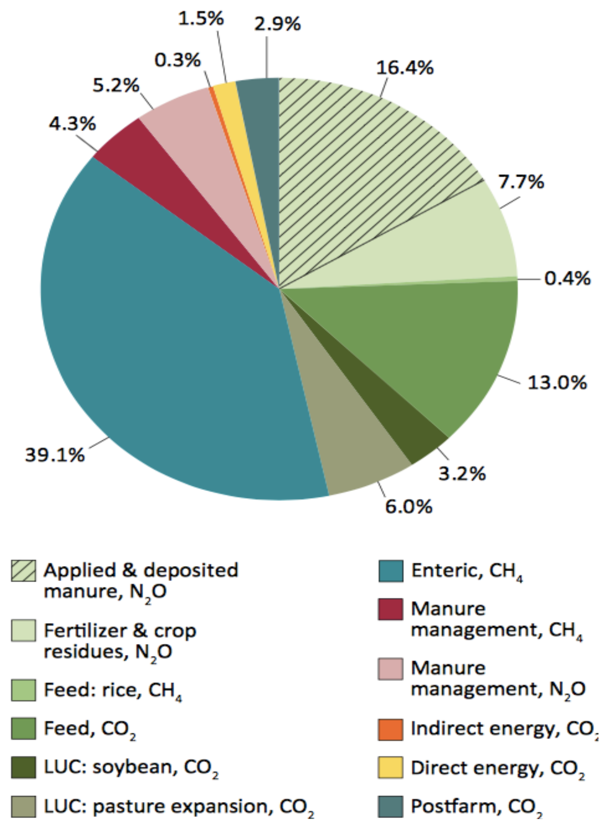


Figure 7: Diagram showing the contribution of livestock to the global GHG emissions. Graphic from Rojas-Downing et al. (2017); data used attributed to Gerber et al. (2013a).



Livestock production emissions come from many sources. There are direct emissions; these are enteric fermentation (gut processes that lead to the exhalation of significant amounts of methane in ruminant animals), respiration and manure. The livestock sector also contributes indirect emissions. These are calculated to be from livestock land use allocation and land change, feed crop production, manure management, on farm activities, livestock product processing and transportation throughout the livestock production cycle (Rojas-Downing et al. 2017) for a review of the literature on particular emission sources in livestock production). A global review of livestock production found that production, processing and transport of feeds was the largest emission source and enteric fermentation was the second largest (Gerber et al. 2013a) (Figure 8). For the East African region feed production and transport are not such major factors in livestock systems. Instead, enteric fermentation, manure management and land use change are the main sources of livestock GHG emissions (USAID 2015). Emission rates vary by production system; in general, extensive pastoral systems are considered to be high emissions systems as they tend to have high methane emissions from enteric fermentation (attributed to the health condition of the animals and the forage quality they consume) and high nitrous oxide rates from unmanaged or under managed manure. With their more directed attention to animal health and feed type and quality, intensive systems are capable of lower emission rates. The emission rates from mixed production systems vary widely depending on the particularities of the livestock type and management strategies.

Figure 8: GHG emissions in the global livestock supply chain by emissions category. Graphic from Gerber et al. (2013a).



Greenhouse gas calculations

Livestock GHG emission calculation is still a developing science. Data is limited or lacking for many agricultural emissions calculations (Rosenstock et al. 2013), and for livestock systems the paucity is even more notable (Caro et al. 2014; Wilkes et al. 2017). A review of GHG emissions studies concludes that though the basic mechanisms of GHG calculations exist, much could be done in the development of cost-effective data gathering methods and generation of regional and context specific emissions factors to expand the capacities for accurate GHG calculations (Olander et al. 2014). The IPCC 2007 report provides the framework for livestock emissions calculations that underpin all current methods. The IPCC established three Tiers of emissions calculations that could be used for national emissions reporting. Tier 1 sets a standardized emission factor for livestock type and emission rates which are then calculated from livestock count numbers. The limitation of this approach is that the emission factor is not varied within a livestock class (by breed, gender or age) nor by production type or feeding regimes; all of these factors have been found to affect emissions rates per animal. Currently though, data for beyond Tier 1 calculations are largely lacking in many countries (Caro et al. 2014). This data lack is salient to national and international planning, as cattle feeding study in Western Kenya, the first of its kind in Sub-Saharan Africa, showed that new methodologies of GHG calculations can decrease emissions estimations by up to 40% over Tier 1 methods (Goopy et al. 2018).

A review of Nationally Determined Contributions (NDCs) reporting of 140 countries found that a few countries manage to parse the livestock by breed or production system and use different emissions factors for these subgroups; this parsing is considered to be a Tier 1b level of calculation as it still relies on an emission factor times livestock number approach. Moreover, as of 2017, only 63 countries had attempted Tier 2 level calculations, and of these only 21 were from developing countries (Wilkes et al. 2017). This is because of the data needs for Tier 2 approaches. 'Tier 2 approaches require more detailed information on different types of livestock in a country, and data on livestock weight, weight gain, feed digestibility, milk yield and other factors reflecting management practices and animal performance' to generate emissions factors per animal and animal intake, and these data are limited, or lacking, for many countries (Wilkes and van Dijk 2018). IPCC Tier 2 methods provide the framework for most deployed Tier 2 analyses and underpin most of the calculation models (see Wilkes and van Dijk 2018 for a review of Tier 2 methods in current deployment and model development).

The IPCC framed Tier 3 calculations as being more sophisticated in the models and the degree of detail in feed types, animal productivity and seasonality than Tier 2. Because of the lack of specificity in what would constitute a Tier 3 calculation versus Tier 2, a major review of emissions calculations methods collapses Tier 2 and 3 together (Wilkes and van Dijk 2018). In this review they note that the majority of Tier 2 attempts are only for limited livestock sectors within a country (mainly cattle) and mostly for enteric fermentation and manure management (Table 3). Tier 2 has been applied in a few countries on goats, buffalo, equids, deer, reindeer, rabbits and others but overall the Tier 2 applications focus on cattle, sheep and pigs as these livestock contribute almost 80% of global livestock emissions (Wilkes and van Dijk 2018). One open source Tier 2 calculation model is the Global Livestock Environmental Assessment Model (GLEAM) which has been used for a worldwide review (Gerber et al. 2013a) and is the basis of recent detailed analysis in East Africa of the dairy sectors in Ethiopia (FAO and NZAGGRC 2017a), Kenya (FAO and NZAGGRC 2017b), Uganda (FAO and NZAGGRC 2019b) and Tanzania (FAO and NZAGGRC 2019a).

In the country profiles in Annex I, data on livestock GHG emissions will be presented from available country and international sources.

Table 3: Chart showing applications of Tier 2 approaches in national emission reports by livestock type and emission type. 140 NDC reports were reviewed, only 62 manage Tier 2 calculations for cattle. Of these only 21 were in developing countries. Chart information from Wilkes and van Dijk (2018).

	Enteric fermentation	CH_4 mnaure management	N_2O manure mangement	N_2O pasture deposit
Cattle	62	57	22	11
Sheep	32	18	17	9
Pigs	18	33	18	-

Livestock and climate change mitigation

Livestock have an important role in food and nutrition security in developing countries (Randolph et al. 2007). Because livestock product demand is expected to increase with rising populations and affluence, there is much institutional interest in the need to decrease emissions from the livestock sector to mitigate against climate change. The term mitigation is used to refer to a suite of practices which include physical and social changes that aim to reduce the GHG emission rate associated with livestock production. Physical changes can include new technologies, modifications of existing management practices, or complete transformation of agricultural production sectors. Mitigation can refer to strategies that aim to reduce total emissions of particular gases, strategies to reduce emissions rates per unit of production and remove CO_2 from the atmosphere and return it into plants or soil-based storage (called carbon sequestration). Emission studies and modelling have shown that there is much untapped mitigation potential in livestock systems. Herrero et al. (2016) conclude that 50% of the global agricultural mitigation potential is in livestock systems.

Just as livestock produce emissions directly and indirectly, livestock mitigation strategies can address both the physical animals and direct emissions, or can address the indirect emissions from the farm management practices, fodder and forage production, processing and transportation that are all part of the global livestock production system. There are many potential technical livestock mitigation strategies for addressing these direct and indirect emissions; four commonly referenced strategies are changing food intake regimes to reduce enteric fermentation, carbon sequestration through land management, modifying manure management and modified fertilizer use in fodder production (Rojas-Downing et al. 2017).

Mottet et al. (2016) utilized GLEAM to run a worldwide emissions review to evaluate a selected set of livestock mitigation technologies by production system and region (see their review for regional and production system details, see Table 4 for their summary). Besides these technical strategies, mitigation also includes changes to the social and political realms such as national policies (e.g. for investment in animal health and breeding services) and international policies (e.g. development of carbon credit initiatives) and the development of economic tools (like price setting, index-based livestock insurance) which can facilitate emissions changes in livestock production.

Table 4: “Most promising mitigation strategies" information from Mottet et al. (2016), generated from their GLEAM analysis of mitigation strategies.

Sector	Level of implementation	Mitigation strategies
Ruminants	Animal	Feed digestibility
		Feed balancing
		Health
		Genetics
	Herd	Overhead herd and production ratio
	Production unit/farm	Grazing managemnt
	Supply chain	Energy use efficiency
		Waste minmizaiton and recycling
Monogastics	Animal	Feed balancing
		Health
		Genetics
	Production unit/farm	Source low Ei feed and energy
	Supply chain	Energy use efficiency
		Waste minmizaiton and recycling

Gerber et al. (2013b) provide a detailed review of potential mitigation techniques that address direct animal emissions. The authors point out that mitigation methods to reduce one source of emissions can concomitantly increase other emissions (e.g. reducing ammonia and nitrous oxide emission from manure through reduced protein diets might increase methane emissions from enteric fermentation). See also Grossi et al. (2019) for a similar mitigation technology review with a clear synthesis of the trades-offs between methane and N_2O for various technical mitigation strategies (Table 5).

These trade-offs become more complex as the social and cultural implications of mitigation strategies are considered. A Tier 1 assessment of global livestock emission trends for 1961 to 2010 found increasing emissions for developing countries but a decrease for developed countries (Caro et al. 2014). This downward emission trend for developed countries is an outcome of having high production and economic returns per unit of livestock based GHG emissions. Thus, many mitigation strategies in livestock systems are aimed at improving overall productivity rates, thereby reducing the GHG per unit of production (of milk or meat). With the almost certainty of expanded livestock numbers in developing countries, national agricultural plans and NDC reports often target the reduction of the emission rate through productivity increases as a national mitigation strategy.

Table 5: Various strategies for addressing enteric fermentation, manure storage and animal management and their potential for mitigating methane and nitrous oxide. Information copied from Grossi et al. 2019, who compiled the data from multiple studies. High ≥30% mitigating effect; Medium=10–30% mitigating effect; Low ≤10% mitigating effect. † Inconsistent or variable results; ‡ Uncertainty due to limited research or data.

		Potential mitigation effect*	
Strategies	**Category**	**Methane**	**Nitrous Oxide**
Enteric fermentation	Forage quality	Low to medium	†
	Feed processing	Low	Low
	Concentrate inclusion	Low to medium	†
	Dietary lipids	Medium	†
	Electrons receptors	High	†
	Ionophores	Low	†
	Methanogenic inhibitors	Low	†
Manure storage	Solid-liquid separation	High	Low
	Anaerobic digestion	High	High
	Decreased storage time	High	High
	Frequent manure removal	High	High
	Phase feeding	‡	Low
	Reduced dietay protein	‡	Medium
	Nitrification inhibitors	‡	Medium to high
	No grazing on wet soil	Low	Medium
	Increased productivitiy	High	High
Animal management	Genetic selection	High	**
	Animal health	Low to medium	Low to medium
	Increase reproductive eff.	Low to medium	Low to medium
	Reduced animal mortality	Low to medium	Low to medium
	Housing systems	Medium to high	Medium to high

There are many technological strategies to improve productivity (e.g. improved animal health through veterinary services and feeding regimen changes) but many of these technical solutions require animal management changes that are in fact social and cultural changes that modify household economies and labour divisions. Shifts of extensive pastoral grazing and smallholder systems to more intensive practices can improve rates of emissions; the potential for such livestock production system transitions (LPSTs) for GHG mitigation at the global level has been shown (Havlík et al. 2014). However, the practicalities and on the ground realities for farmers and herders of shifting from extensive, or smallholder practices are under considered in these models of potential mitigation.

Havlík et al. (2014) themselves point out that their mitigation models fail to adequately address the multifunctionality that livestock hold in household economies when considering livestock valuation in the models. Similarly, Herrero et al. (2016) also modelled mitigation outcomes of field tested management options for modification of direct emissions and found a number of strategies with high potential for mitigation; these are: carbon sequestration through improved grazing management; improved feed digestibility; use of feed additives; avoidance of land use change through ruminant system intensification; animal management; rangeland rehabilitation; carbon sequestration through legume sowing; and manure management[4]. In discussing the ways in which intensification (also called "land-sparing") can have environmental improvement benefits along with the GHG mitigation outcomes, Herrero et al. (2016) state 'at the same time, establishing the societal impacts of land-sparing opportunities, in terms of livelihoods, employment, economics, gender and equity, is essential for understanding their feasibility. This area needs to receive urgent attention due to its policy relevance' (Herrero et al. 2016). Thus, mitigating climate change impacts of livestock cannot be done outside of the food, nutrition and livelihood context in which the livestock exist. See below in climate-smart agriculture for further discussion of mitigation technologies and opportunities in East Africa.

Climate-smart agriculture

CSA is a recently developed concept (FAO 2010) which has the goal of providing a conceptual system for evaluating agricultural production systems across multiple factors simultaneously. Derived out of interest in operationalizing sustainable development's three dimensions (economic, social and environmental), the CSA framework allows institutions to analyze current and future agricultural production systems on food security and climate change factors at the same time. CSA is oriented toward:

1. sustainably increasing agricultural productivity and incomes;
2. adapting and building resilience to climate change; and
3. reducing and/or removing greenhouse gases emissions where possible (FAO 2013).

Under CSA evaluations, an agricultural[5] production practice is deemed CSA when it 'sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food security and development goals' (FAO 2013). As there are many potential trade-offs between increasing productivity, mitigating GHGs and adapting for resilience in the face of climate change, 'the "smartness" of a given CSA technology is dependent on context, and can vary considerably between different production systems and locations' (Sova et al. 2018).

[4] Unlike many studies Herrero et al. (2016) acknowledge that reduced consumption of livestock products is a possible mitigation strategy. They note that modeling of this needs to be done to be certain of the mitigation outcomes as there are ramifications on land change, other food production systems and other food processing emissions that come with decreased animal product consumption.

[5] Herein agriculture encompasses all agricultural production systems, including livestock and sometimes fisheries and forestry.

CSA implementation guidelines have been developed (FAO 2013) but CSA as a practical framework for evaluating and planning for agricultural sector development is still in its introductory phases (see Lipper et al. 2014 and SIDA 2017 as examples of the CSA framework being introduced). However, studies on agricultural practices deploying the CSA evaluation framework are emerging, as are more reflexive reviews of the concept and its potential implementation (Rosenstock et al. 2015b and 2019b; Sova et al. 2018). These CSA reviews point out that the potential toolkit of adaptation, mitigation and development (productivity) practices is very broad and currently much of the practical application and outcomes of CSA are based on case study analysis (for example, see the East African case study reviews from Dinesh et al. 2014; Kipkoech et al. 2015; Nyasimi et al. 2014 and Njeru et al. 2016). These context specific case studies are fitting as CSA by definition has to 'take into consideration the social, economic and environmental context where it will be applied' (FAO 2013). However, early critical analyses of the CSA concept focus on failures in CSA literature to maintain the broadness of the concept while considering the context specificity of the project; one particularly virulent review states:

> Balancing priorities at the intersections of food security, adaptation and mitigation, however, always occurs in the context of region specific conditions and cultures. Why should resource poor farmers invest in agricultural practices that may reduce emissions if there are few if any immediate benefits related to food or water security? ('It's hard to be green when you are in the red.') CSA, as currently conceived and implemented, fails entirely to recognize different actors, incentives and interactions between different (but related) provisioning demands for food, water, energy, materials and ecosystem services. (Neufeldt et al. 2013)

This critique speaks to the fundamental challenge for the organizations that wish to adopt a climate-smart framework for their policies and projects. Interest in deploying CSA has 'led many development practitioners, scientists, and governments to the question *what is CSA and what is not CSA?'* (Rosenstock et al. 2015a). The push to have a singular set of "CSA practices" for deployment is the risk of CSA that Neufeldt et al. (2013) are writing against; Rosenstock et al. (2015a) point out that the very question "what is and what is not CSA?" creates a dichotomy that is false to the fundamental principles of CSA[6].

Balancing across the need to create generalized evaluative frameworks and deployable toolsets while also allowing for context specificity is the current challenge in CSA; this challenge is being met through more controlled field experiments (Ogada et al. 2018) on testing the concept of climate-smart villages) and systematic review of agricultural projects and technologies on their adaptive, productivity and mitigation capabilities. Sova et al. (2018) did a worldwide review of potential CSA technologies, in which over 1,700 combinations of technologies, production systems and regions were assessed. Rosenstock et al. (2015b) did a systematic review of agricultural studies to look for synergies between the three pillars of adaptation, production and mitigation. They found that most projects analyze for only one of the pillars, but pairwise comparison of productivity versus resilience outcomes were possible in 754 studies. These comparisons showed that though win-win outcomes are possible, it also possible for an intervention that increases productivity has negative impacts on resilience in one application but is the reverse in other situations. Another systematic review of agricultural projects in East and Southern

[6] See also Taylor (2017) for an analysis of how the CSA concept is being turned to a technical fix framework in World Bank projects that belies its potential as a holistic evaluative tool.

Africa has shown that data is largely lacking for analysis of CSA win-win-win scenarios as studies often lack site specific data on mitigation (Rosenstock et al. 2019b). The need to cross correlate between projects and datasets to aid in regional or site specific CSA planning and projects led to the development of an online database for CSA decision support[7].

Climate-smart livestock

In reviewing climate change impacts on livestock, and the adaptation and mitigation potentials, Thornton et al. (2009) point out that the massive world assessment reports of the IPCC (2007) and the Millennium Ecosystem Assessment 2005 have 'yawning gaps in their treatment of livestock systems in developing countries.' This oversight has continued; even within recent CSA work the livestock sector has not been as widely developed or studied as crop systems. In the review of over 1,700 technologies, production systems and regions by Sova et al. (2018) only 18% of identified climate-smart technologies were for livestock systems[8], despite the worldwide relevance of livestock systems in agricultural production and food and nutrition security. This CSA review points out that 'stakeholders, public as well as private, aiming to develop climate-smart livestock investments often lack adequate information and tools to support them' and points readers to a new livestock investment and development decision making tool[9]. It is telling that a major review of CSA approaches has to direct readers to a non climate-smart approach for tools on livestock sector decision making.

Most of the identified and commonly deployed climate-smart livestock approaches are the same strategies and techniques identified for livestock emissions mitigation. This is indicative of the interest in mitigation that is driving current development goals and international investment.

Identified climate-smart livestock approaches include animal health and productivity through:

- Forage and fodder supplementation;
- Veterinary service provision;
- Supporting breeding programs to generate crosses between indigenous and exotic animal breeds, or to support indigenous breed crosses.

[7] https://era.ccafs.cgiar.org/ launched in October 2019, the Evidence for Resilient Agriculture database 'contains more than 75,000 data points from about 1,400 scientific studies conducted in Africa that describe the impacts of more than 100 agricultural technologies on more than 50 indicators of productivity and resilience (e.g., net returns, yield stability, soil carbon, resource use efficiency). This core combines with a rich database of climate, soil and social information (e.g., distance to market) to produce an unparalleled resource to support science-based decision-making and the identification of locally adapted but scalable options.'

[8] The authors also note that aquaculture practices also are overlooked, with only 2% of the evaluated "climate-smart" approaches addressing aquaculture.

[9] https://www.sustainablelivestockguide.org/ though not premised directly on the climate-smart concept, the seven principles of sustainability that underpin the guide overlap with the CSA pillars of productivity, adaptation and mitigation. 'This web-based platform is both a practical instrument and an information resource for developing environmentally sound livestock production systems. The ISL Guide provides guidance, suggested activities and indicators needed to ensure livestock projects are environmentally sustainable.'

Land management oriented climate-smart livestock approaches include

- Pasture and rangeland projects for rehabilitation;
- Rotational grazing;
- Introduction of high yielding forages;
- Field level manure management.

Climate-smart livestock approaches also include projects that generate linkages between crop and livestock systems. These linkages include

- Utilizing crop residues as feed sources;
- Manure composting for soil amendments;
- Biodigestors for energy production;
- Silvopasture systems.

Climate-smart approaches can even potentially include restructuring of livelihood strategies:

- Changing livestock stocking patterns (herd management);
- Encouraging a market orientation (selling more milk, selling more animals in total, selling animals younger and more frequently);
- Switching livestock (encouraging cattle to camel conversion, or cattle to small ruminants)
- Diversification through adoption of new livestock types (encouraging poultry farming);
- Diversification through production system transformations (facilitating transitions from pastoral to agropastoral production);
- Facilitating intensification of livestock systems (from smallholders to medium holders, particular interest given to dairy systems)

With all the above, the actual application of an approach needs to be evaluated in a specific context for its capacities to positively impact productivity, adaptation and mitigation to be understood. The trade-offs between these are not always the same across applications. In the following country profiles, country specific work in climate-smart livestock will be discussed and potential for further opportunities for climate-smart livestock approaches will be identified. Generalized adaptation and mitigation issues and the potential for climate-smart livestock in the East African region will be further discussed in the conclusions.

Summaries from the reviewed countries

Livestock production

Livestock contribution to GDP and livelihoods

All the countries except Djibouti and Somalia have a clear majority of their population living rurally (Table 6). Somaliland is also similarly split (53% urban) and for both this transition to such a high urban population is recent. The long running war and civil unrest coupled with frequent serious droughts have driven this rapid urbanization. An indication that this high urban population for Somalia is relatively new comes from the fact that the percentage of the population relying on agriculture is more than the population living in urban settings and the agricultural sector still provides more than half of the GDP. Eritrea and Djibouti are the only countries in the region where the agricultural sector is not at least a ¼ of the national income (Table 6). However, it is important to note the difference between considering the role of agriculture in the national economy versus its role in household economies. For example, for 22% of the population that lives rurally in Djibouti, livestock production is the basis of 90% of household livelihoods. A focus at the national level on GDP obscures the significance of livestock production at the household or regional scales.

Table 6: The role of livestock in GDP and livelihoods, some factoids. Country population numbers, % rural population, % of population in agriculture and % GDP from agriculture data gathered from the World Bank data portal at https://data.worldbank.org/. For statistics on population, rural and % agriculture columns are from 2018 for all countries, except Eritrea which is from 2011; agriculture % GDP data years are 2018 for all except Eritrea (2009), Somalia (1990), Rwanda (2017) and Tanzania 2017. Data on % GDP livestock, the livelihood notes, and all of Somaliland data are from various sources referenced in the Country Profiles. NA = not available

Country	Population	Rural pop (% total)	% pop in agriculture sector	% GDP agriculture sector	% GDP from livestock	Livestock and livelihood/production strategies
Eritrea	3,212,970	64	63	14.1	6.6	Mostly traditional extensive pastoral/agropastoral
Djibouti	958,920	22	50	2.3	3	80% pastoral/20% agropastoral
Somalia	15,008,150	55	72	62.7	61	Livestock is the main livelihood of 60 to 65 % of the population
Somaliland	NA	NA	NA	NA	28.4	26% households in nomadic pastoralism, 42% settled agropastoral
Ethiopia	109,224,560	79	66	31.1	19	95% households are smallholders; 63% mixed crop-livestock, 36% pastoral and agropastoral

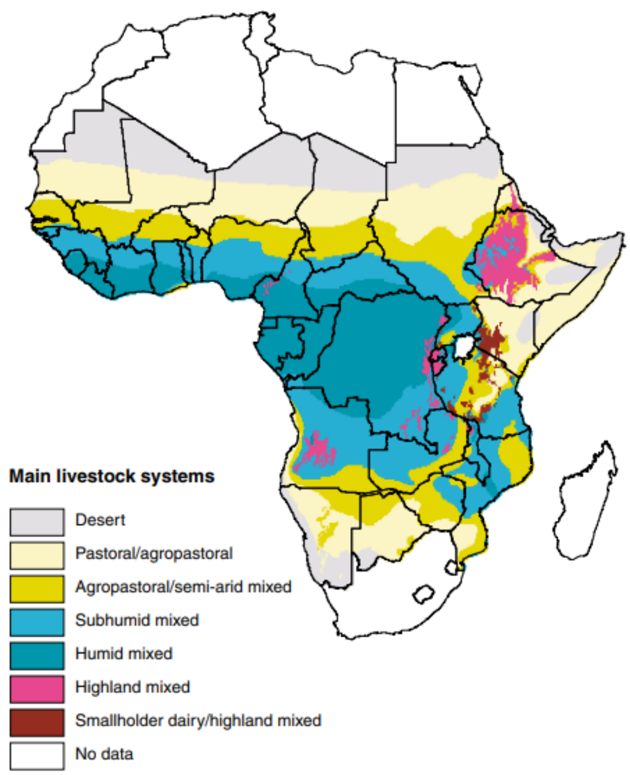
Country	Population	Rural pop (% total)	% pop in agriculture sector	% GDP agriculture sector	% GDP from livestock	Livestock and livelihood/production strategies
Kenya	51,393,010	73	57	34.2	12	Smallholders occupy 98% of land holdings and produce 75% of agricultural production; 50 to 70% of livestock in the ASAL (pastoralism, ranching, agropastoral)
Uganda	42,723,140	76	71	24.2	1.7	Smallholders own 80% of livestock in-country; 70% of households have at least one livestock; 26% of households own cattle
Rwanda	12,301,940	83	67	29.0	3.6	70–80% livelihood basis in smallholder agriculture; 70% households have livestock; 66% mixed crop-livestock, 36% only crop, 1% livestock only
Tanzania	56,318,250	66	66	28.7	8	80% livelihoods in agriculture; 55.8% crop only, 44.8% mixed crop-livestock, 2.4% livestock only

Production systems

Classifying a country's livelihood practices can be done at broad scales or with fine grain analysis and the level of correspondence between countries can be found to be great or highly variable depending on the type of analytics used. The general move toward the agricultural production systems model creates a method to highlight similarities between the countries. Otte and Chilonda's livestock review included the development of a distribution map that places a range of production types into the generalized agroecological zones (Figure 9). This is important because national borders belie the historic and current interconnectedness of pastoral peoples across the GHA; broad production system groupings can be helpful when it encourages contemplation of the interconnected nature of pastoral production in the arid and dryland areas of the GHA.

However, this tendency toward production system aggregation can begin to obfuscate important differences. Using the Otte and Chilonda map as an example it can be seen how they aggregate pastoral/agropastoral systems in the arid areas (light yellow) and also generate an agropastoral/semi-arid mixed crop-livestock sector (darker yellow). At this scale, collapsing agropastoral with mixed is understandable; however, what is found in the review of the nine countries is that these categories are so often collapsed together or used interchangeably with frames of "smallholders" that the true heterogenicity of the livestock and crop systems are obscured. For planning and development purposes it is important to always bear in mind that what are grouped as mixed crop-livestock systems can in fact be very different practices. As it was put in the FAO world review 'given the heterogeneity of the group, it is meaningless to generalize' (FAO 2011). And mixed crop-livestock can be different from agropastoral production in the same landscape. Even if the discussion is limited to smallholder mixed crop-livestock, which is a major production across the reviewed countries, these can still be widely different across a nation or even a sub region in regard to actual animals kept (by type and number), method of animal keeping and crops produced as well as having 'considerable variation in assets, income and social customs' (FAO 2011). National planning efforts should bare these distinctions in mind, and where possible, turn to more nuanced livelihood mappings.

Figure 9: Main livestock prodution systems across Africa. Image from Otte and Chilonda (2003).



Livestock populations

National herd sizes are not surprisingly largest in the largest countries (Ethiopia and Tanzania), but variation exists in animal types and densities across the region (see table 7). Notable differences include Somalia's world dominance in camel numbers and Rwanda's very small sheep numbers. Utilizing the herd count of cattle, goat, sheep, camel and swine and published country land size gives a quick glance at the differences in animal densities (see table 8). Rwanda has the highest animal densities and despite its total national herd size, Tanzania has a relatively low mammal livestock density (for density numbers by species and sub regional distributions see the referenced country statistical and review reports). These animal densities vary within country borders and across AEZs (see Figure 10). While most of the high density animal populations are in the moister highlands, Somalia and Somaliland also contain high densities on arid lands. These density differences have implications for which climate change adaptation strategies and mitigation strategies will be feasible or advisable in areas.

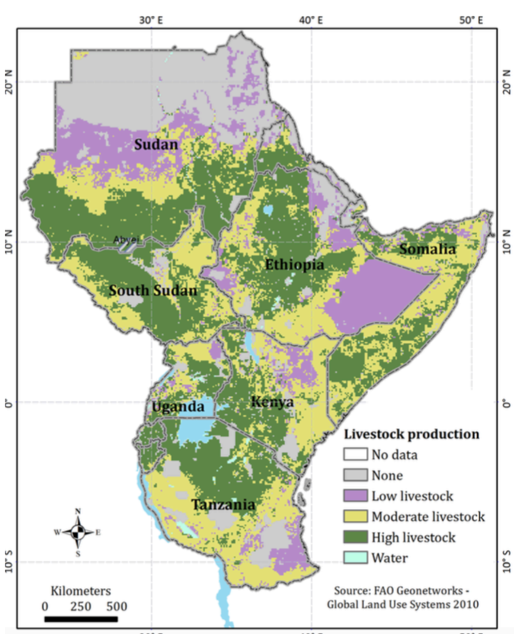
Table 7: National livestock numbers. Data for each country as reported in the country reviews is sourced from EMoI 2012 (Eritrea); Knips 2004 (Djibouti), Too et al. 2015 and Shapiro et al. 2017a (Somalia and Somaliland); KNBS 2010 (Kenya); UBOS 2018 (Uganda); Rwanda, Shapiro et al. 2017b; Tanzania, URT 2018. NA = not available

Country	National livestock					
	Cattle	Sheep	Goats	Camels	Poultry	Swine
Eritrea	1,900,000	2,100,000	4,700,000	318,914	1,100,000	NA
Djibouti	295,995	464,359	511,449	67,000	NA	NA
Somaliland	414,000	9,048,000	8,875,000	1,720,000	NA	NA
Somalia	4,700,000	12,983,000	17,812,000	6,768,000	NA	NA
Ethiopia	55,200,000	29,000,000	29,000,000	4,500,000	50,000,000	29,000
Kenya	17,500,000	17,000,000	27,700,000	3,000,000	31,800,000	335,000
Uganda	14,189,000	4,445,000	16,034,000	32,000	47,579,000	4,109,000
Rwanda	1,390,000	700,000	2,940,000	NA	7,000,000	1,800,000
Tanzania	30,670,000	5,560,000	19,000,000	NA	40,350,000	1,900,000

Table 8: Calculated national densities of ruminants and swine

Country	Mammal/km^2
Eritrea	77
Djibouti	58
Somaliland	117
Somalia	91
Ethiopia	107
Kenya	113
Uganda	161
Rwanda	259
Tanzania	60

Figure 10: Livestock production levels (ICPAC and WFP 2018b)



Food insecurity

Food insecurity is a problem for all the reviewed countries, whether at a national level or only in particular sub-regions. Of the countries that have enough data for a Global Hunger Index calculation, all are considered in "serious" condition in relationship to their potential for food insecurity (see Table 9). The reviewed countries with the highest proportion of their landmass in lowlands (Eritrea, Djibouti, Somalia) all rank in the highest three countries (out of 119) on the component parts of the GHI. Eritrea is one of the top three countries (out of 119) for childhood stunting, with more than half suffering from stunting. Djibouti is among the three top countries for childhood wasting (calculated at 16.7% of children) and Somalia is in the top three for both undernourishment (50.6%) and has the highest rate of child under 5 mortality (13.3%) of all 119 countries (von Grebmer et al. 2018). All reviewed countries have high PoU (see Table 10) despite there being downward trends in PoU for Sub-Saharan Africa (from 34% in 1991 to 20% in 2015) (Kedir 2018). Food insecurity for the East African region[10] was calculated to be at 46%, but projections through to 2028 suggest a potential decline in food insecurity for the region, with the biggest security gains likely to be in Ethiopia, Rwanda, Tanzania and Uganda (Thome et al. 2018). However, this review looked at economic growth indicators and commodity prices for its assessment of access to food and did not address climate change and its potential impacts on food production and accessibility in East Africa. Other reviews are not so sanguine. After a decade of steady decline, the number of people suffering from hunger in the world has slowly increased for several years in a row, underscoring the immense challenge of ending hunger by 2030 (FAO 2019).

Table 9: Global Hunger Index scores and rankings for the reviewed countries.
Scores on the GHI are ranked as low (≤ 9.9); moderate (10.0–19.9); serious (20.0–34.9); alarming (35.0–49.9); and extremely alarming (≥ 50.0). Data from GHI from von Grebmer et al. (2018). NA = not available.

Country	GHI	Rank out of 119	Severity scale
Eritrea	NA		
Djibouti	30.1	98th	Serious
Somalia/ Somaliland	NA		
Ethiopia	29.1	93rd	Serious
Kenya	23.2	77th	Serious
Uganda	31.2	105th	Serious
Rwanda	28.7	91st	Serious
Tanzania	29.5	95th	Serious

[10] In this worldwide food insecurity calculation, East Africa includes Burundi, Chad, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, Sudan, Tanzania and Uganda.

Table 10: PoU as a percentage of the entire population. All data from FAO et al. (2019). NA = not available.

Year	PoU in the total population
2016–2018	%
Eritrea	NA
Djibouti	18.9
Somalia / Somaliland	NA
Ethiopia	20.6
Kenya	29.4
Uganda	41.0
Rwanda	36.8
Tanzania	30.7

Climate change and livestock

General model consensus is for warming trends for the broader East Africa region. Such consensus does not exist for precipitation. Some world models (IPCC predictions included) suggest overall precipitation increases for Eastern Africa. However, these precipitation increases are often based on increases in extreme precipitation while at the same time predicting shorter rainfall seasons and increased interannual variability. In contrast to the IPPC predictions many downscaled models for the region show decreases in rainfall. These regional models highlight the ways in which Eastern Africa precipitation is influenced by local conditions (i.e. the warming of the Indian Ocean, (Funk et al. 2005) which are underevaluated in world models, especially in comparison to the Pacific dominated El Niño/La Niña. Country specific precipitation models highlight the extreme uncertainty that exists on future precipitation patterns; this uncertainty exists at the regional and local scales that are relevant to farmers and livestock keepers.

Throughout all the countries there are similar concerns for the direct effects of climate change on livestock such as heat stress, water and forage availability, disease vector spread, etc. (see the Topic Review on Agriculture and livestock production under climate change). For the coastal countries, they have the added risk of sea level rise and subsequent salinization of coastal plain waters. Erosion under extreme rains is a threat in many highland and hilly areas, and is of particular concern for Rwanda with its dense hill side farm tradition and friable soils. All the reviewed countries face shifts in their climatic zones. These shifts can have positive impacts on land arability, increasing potential cropping zones. Changed rainfall regimes could shift the regions of “arid drylands” which are most suited to extensive pastoralism.

Livestock and GHG emissions

All reviewed countries have filed at least one communication to the UNFCCC and have generated some GHG emissions inventory. The depth of the reporting varies widely between countries. In each country review the national report is given as well as any contrasting claims. Most countries reported an estimation of the agricultural contribution to the national GHG emissions (see Table 11). For Tanzania, the agricultural contribution was second to Land Use Change which included large emissions from crop residue burning. For Rwanda, the Agriculture sector contribution is the largest as Land Use Change was calculated as contributing a large sink for CO_2, thus the net reported emission for Land Use is low. Djibouti's agricultural contribution was miniscule, reflecting again the concentration of economic activity in the city and port infrastructure. For all reported agricultural contributions, enteric fermentation was the highest portion.

Table 11: Agriculture sector's contribution to the total country GHG. Data for Djibouti from its 2001 NDC, all other data from USAID Greenhouse Gas fact sheets per country. NA = not available.

Country	**Agricultural sector contribution as % of total**	**Land use change and forestry, % of total**
Eritrea	NA	NA
Djibouti	8	NA
Somaliland	NA	NA
Somalia	NA	NA
Ethiopia	61	18%
Kenya	62.8	contested
Uganda	48	18.57
Rwanda	35.5	11.4 (net)
Tanzania	17.3	72.7

In order to provide more cross region comparison, data was also collected from the World Bank data portal. As has been seen above, and in each country review, the agricultural percentage contribution to total CO_2e varies widely between the countries. However, for all countries the agricultural sector contributes over 80% of the nitrous oxide emissions, and for all except Rwanda, over half of the methane emissions (see Table 12).

Table 12: Estimated GHG emissions with agricultural methane and agricultural nitrous oxide. (World Bank 2016)

Country	**Total GHG**	**CO_2**	**Agricultural methane**	**Agricultural methane as % of total NH_4**	**Agricultural nitrous oxide**	**Ag nitrous oxide as % of total NO**
	kt CO_2e	kt CO_2e	kt CO_2 e	%	kt CO_2e	%
	2012	2014	2008	2008	2008	2008
Eritrea	4980	697	1821	66	1071	88
Djibouti	2720	722	382	63	208	84
Somalia	21,920	608	12,346	78	4367	91
Ethiopia	185,290	11,599	42,678	71	32,521	88
Kenya	54300	14,287	15,468	56	10,199	88
Uganda	80,730	5229	13,735	66	12,994	86
Rwanda	6690	840	1062	39	901	80
Tanzania	235,330	11,562	15,265	60	9972	83

Reviews of the world GHG emissions acknowledge that the historic contribution of GHGs by the nations of the Greater Horn of Africa are proportionally minuscule, whether calculated as emissions per capita (Table 13) or national contribution to worldwide GHG emissions totals (see Table 14).

Table 13. Emission rates per capita. All country data is from 2014, except Eritrea (2011). For comparison, the world average for 2014 was 4.8 mt per capita. (World Bank 2016)

Country	Metric tons per capita
Eritrea	0.8
Djibouti	0.2
Somalia	0.0
Ethiopia	0.1
Kenya	0.3
Uganda	0.1
Rwanda	0.1
Tanzania	0.2

Table 14: Contribution of selected countries to world emission total. Data sourced from USAID Greenhouse Gas Emissions Factsheet: East Africa (2015), which utilizes WRI CIAT 2011 data.

Country	Total GHG ($MtCO_2eq$)	Contribution to global GHG emissions
Djibouti	1	0.003
Ethiopia	141	0.3
Kenya	60.2	0.13
Uganda	49	0.1
Rwanda	7.59	0.015
Tanzania	172	0.59

Intended Nationally Determined Contributions (INDCs) mitigation and adaptation plans

For global GHG reduction, the developed world should be at the forefront of aggressive mitigation action to reduce their own total GHG emissions. However, the role and responsibility of even small emitters was put very succinctly and gracefully by the Eritrean government in their INDC mitigation and adaption plan:

> To reiterate the obvious, countries do not contribute equal amount of GHG emissions to the atmosphere, be it in absolute or relative terms. The largest emissions come from the developed countries. Emissions from the LDCs, a group of countries to which Eritrea belongs is negligible. Yet it is these countries that at present suffer most from the impacts of global warming and climate change due to the already vulnerable ecosystem and the geographic location of their habitat as well as their low adaptive capacity. Notwithstanding this fact, climate change knows no boundaries; no country has the chance of being spared…
>
> Striking the right balance between the overwhelmingly urgent necessities to reduce emissions on one hand and expediting the achievement of pressing needs for economic progress may not be so easy, particularly for the LDCs. Despite this and the legitimate right that these countries have to a fair share of the atmospheric space, Eritrea upholds the basic tenets of the Convention that require all parties to make ambitious contributions towards emissions reductions on the basis of equity and in accordance with their common but differentiated historical responsibilities and respective capacities (State of Eritrea 2018).

In this context, the interest in the emissions from livestock production in the reviewed countries becomes understandable. Though the overall emissions from these countries is small, within that emissions profile agriculture was the largest contributor in Kenya, Rwanda and Ethiopia. Agriculture is likely the largest sector in Eritrea, Somalia and Somaliland with data remaining limited. Tanzania's Forestry and Land Use sector is the largest emitter. Within all countries, reported agriculture emissions, enteric fermentation and manure left on fields are the largest contributors to the calculated CO_2e. This is true for the dual reasons that methane and nitrous oxide are potent GHGs toward global warming, and these countries have low levels of industrialization and energy use, so these sectors contribute relatively little CO_2 to the total emissions.

Moreover, these emissions are from livestock whose emission rate, often called emission intensity (amount of gas per amount of economic return or product produced) is often very high. A recent estimate of emissions from livestock was done for 237 countries (Caro et al. 2014). They calculated emissions intensities for each country, calculated as emissions per dollar of total economic output from the livestock sector. Eighteen of the twenty countries with the highest emission intensities are in Afica. Eritrea has the highest emission intensity of all the countries studied, Niger was second and Ethiopia third (Caro et al. 2014). Similarly, reviews of enteric fermentation emission rates for dairy production by types of animals and types of production systems in Ethiopia, Kenya, Uganda and Tanzania have shown that emission rates per unit milk produced vary widely between production systems. This project identified the Sub-Saharan African dairy sector as offering "sizable reduction opportunities" as the smallholder dairy sector is pervasive in the East African region (FAO and NZAGGRC 2019a).

However, despite these "sizeable reduction opportunities" the nine countries INDCs are lacking in proposals to directly address enteric fermentation in their mitigation proposals. In 2017, FAO did a review of published NDCs from East Africa to evaluate potential gaps in countries emissions calculations and the identified adaptation and mitigation potentials. This review notes that though agricultural emissions from certain sectors are high, 'the gap analysis evidence insufficient coverage of policies and measures aiming to reduce biomass burning on grassland (i.e. savannah burning); improve soil management; and improve livestock feeding' (FAO 2017). This is a significant oversight as improved forage and fodder intake are identified as having high mitigation potential in livestock system reviews (and would have productivity gains too).

This current review also found that the agriculture sector is not included in the INDC mitigation measures for Eritrea, Uganda, Rwanda and Tanzania. Djibouti does not directly include the agriculture sector, but it is referenced tangentially under the forestry mitigation that lists silvapastoral systems as a conditional mitigation strategy. Somalia, Ethiopia and Kenya have agricultural oriented mitigation plans. For Ethiopia, agricultural mitigation is to be achieved by increased crop and livestock productivity. For Somalia, mitigation will come from sustainable land management practices and through productivity increases that are coupled with decreasing vulnerable populations through promotion of agriculture and farming. Kenya includes the agriculture sector in its mitigation priorities through its promotion of CSA. All eight countries with published INDC adaption plans include agriculture production in their adaptation plans. Djibouti directly mentions supporting pastoral production.

Climate-smart livestock

CSA by definition needs to address issues of food security (the productivity pillar), the long-term viability of the household production and environment in the face of climate change (adaptation pillar), and where possible, help address countrywide GHG emissions (the mitigation pillar). Determinations of which practices are climate-smart need to be done in relation to the specific conditions of the agroecological region in connection with the existing sociopolitical realities or options that exist in those sites. Specific livestock production practices can be classified in relation to their potential GHG emissions and general adaptation technologies identified for production systems, but sweeping generalizations that a livestock production system is or is not climate-smart needs to be avoided and any such broad claims should be critically evaluated.

CSA is being adopted and implemented under different programmatic initiatives. For some countries, national level CSA goals and policies have been set. Kenya has a National CSA framework. The government of Eritrea has developed, with the FAO, a set of CSA priority guidelines for FAO's program in Eritrea. Ethiopia lists CSA as one of the tools for reaching their Climate Resilient Green Economy. Tanzania includes CSA as a part of improving its agricultural productivity.

There are many CSA projects that have been implemented and studied in the reviewed countries. The majority of applications have been for crop systems. For climate-smart livestock the most commonly referenced technologies intersect within three main themes: improved animal health, feeding and animal genetics (see Table 15).

Table 15: Potential climate-smart livestock technologies and approaches. List generated from CSA studies and reports from the nine reviewed countries.

Climate-smart livestock interventions
Crossbreeding and pure exotic breed
Selective breeding among indigenous breed
Animal health service provisions (vaccinations, disease and pest control measures, artificial insemination)
Livestock diversification (type of animal kept, mix of animals kept)
Stocking (overall herd sizes, preemptive destocking in droughts, restocking support)
Zero grazing
Enhancing quality and utilization of concentrate feeds & supplementation using oilcakes
Enhancing the utilization of crop residues
Utilization of industrial by products in rations for livestock
The use of feed additives: plant extracts and rumen modifiers
Introducing high yielding forages
Grass–legume association in intensive dairy production
Grass–legume association in semi-extensive dairy production
Integrating leguminous fodder trees and shrubs into existing systems
Range/pastureland improvement
Improved pastures (e.g. introduction of climate smart Brachiaria grasses)
Manure composting and application
Use of biodigestors in intensive dairy production
Financial instruments (credit access, livestock insurance, index-based livestock insurance

Conclusions

> 'Livestock bring value, versatility and resilience to mixed farming households, which are more robust and food secure with animals than they would be without them.' (FAO 2011)

For climate change adaptation and mitigation mixed crop livestock systems are offering opportunities for win-win scenarios where production quantity per unit inputs of food and water can be improved (Duncan et al. 2014). However, the synergies and trade-offs between crop production and livestock production encompass choices and outcomes on many factors such as distribution of labour, investment strategies, use of crop residues, water usage, land management for nutrients and erosion among others. These factors can be judged 'positive in one context and negative in another […] This highlights the complexity of mixed systems and the difficulties associated with making broad statements about what works and what does not: local context and the perceptions and objectives of individual farmers may change everything' (Thornton and Herrero 2015). External judgements of the value of livestock in mixed systems, or any production system for that matter, can fail to capture the full non-market values that livestock have in a household (Moll 2005).

Smallholder production is recognized as an important livelihood strategy of much of the highland populations throughout the reviewed countries (see Table 6 above). But with the general trends in undervaluing livestock contributions to livelihoods a necessary area of work is on disaggregating the smallholder systems in detailed studies regarding their ownership and use of livestock. This is important as diversification and intensification of smallholder practices are possible productivity and mitigation strategies, but they are only viable if the livestock developments fit into household practices and all of the non-market values of the livestock continue to be met.

> 'The ability to withstand environmental shocks is a defining feature of pastoralism, but pressures on pastoral systems – many of which are a direct result of antipathetic policies – have undermined the customary ability to cope.' (Hatfield and Davies 2006)

In the arid lowlands of the reviewed countries there are frequent and ongoing famine or food insecurity crisis in the regions traditionally occupied by pastoral production. Some take these crises as evidence for the non-viability of pastoralism. However, these current problems are not a function of pastoralism qua pastoralism but are rather a problem of pastoralism's position in modern state apparatuses of governance coupled with the increasing drought induced landscape variability. Historical trends of expatriation through land enclosures and general decreases in freedom of mobility (national borders, institutional pressures to settle, privatization of land holdings) undermined the viability of pastoral production systems. These barriers to mobility exacerbate the risks imposed by climate change to pastoral production systems (Ericksen et al. 2013).

Pastoral systems are seen as needing support in some of the countries NAPA and INDCs (see for example Eritrea and Djibouti's interest in maintaining pastoralism and decreasing urban immigration), and in others the pastoral populations are addressed as "vulnerable" (Ethiopia) and policies are geared toward livelihood transformations and transitions. Pastoral intervention strategies should be developed that can address the dual goals of both strengthening and encouraging pastoralism where it is the most viable livelihood strategy and developing and supporting exit strategies from pastoralism for households, and or regions, where it is no longer a viable livelihood strategy[11]. Tool sets do exist to aid in intensifying extensive systems, such as support for animal health management, fodder supplementation schemes (see Somalia's plan for strategic fodder reserves) and aids for destocking and restocking geared toward supporting viable pastoral production. Policy tool sets particularly include landscape level protections that dissuade land enclosures and that can aid transboundary movements of herds.

> 'Ideally, decision-making processes are evidence based and informed by objective information. The provided evidence should assist in narrowing down long lists of potential solutions into real portfolios of context-specific action.' (Notenbaert et al. 2017)

Many of the reviewed countries are lacking in quality data regarding livestock numbers, types and production systems, this is especially true for Somalia, Somaliland, Eritrea and Ethiopia in its lowland region. Meteorological stations are spartan across the countries making historic trend analysis difficult and undermining potentials for accurate future monitoring. Country reporting of GHG emissions has relied on Tier 1 methodologies as detailed data on animals and fodder are often not available. Detailed emissions factors for the variety of livestock systems are limited to the work that has been done on dairy value chains in Kenya, Ethiopia, Uganda and Tanzania. For all the reviewed countries the ability of households and nations to adapt their livestock systems to be resilient in the face of climate change will be dependent on having the right information that is accessible, timely and actionable. Support for data collecting research is needed, as is support for institutional capacity building for information dissemination and use.

[11] With careful attention given to how and by whom judgements of the non-viability of pastoral systems are made.

Annex I: Country profiles

Eritrea

Agricultural production and agroecological zones

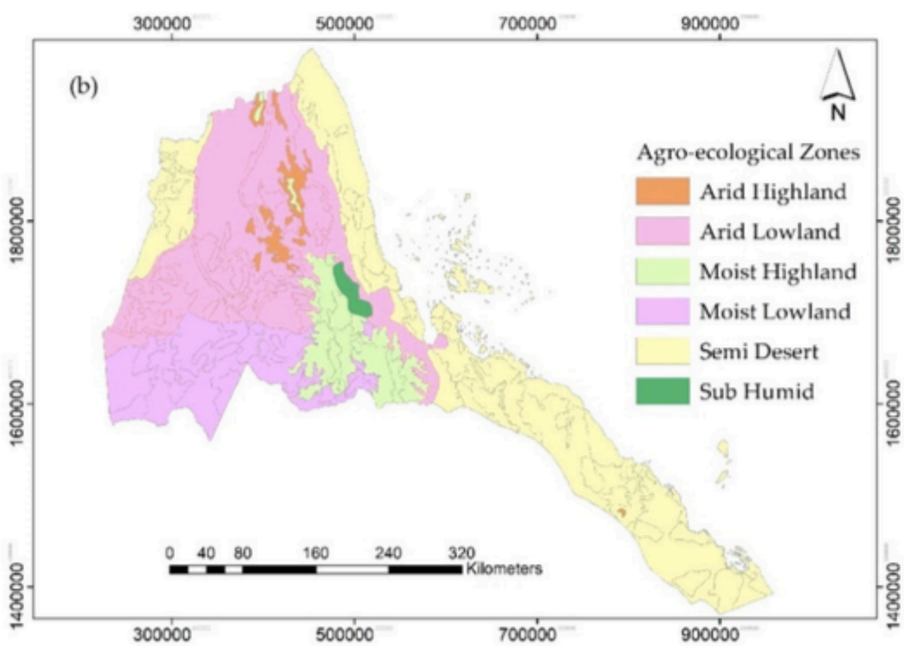
The agriculture production sector consists of food crops, livestock, fishery and forest production of which the major agriculture production sectors are the crop and livestock systems. Though agricultural production accounts for only 12% of the GDP, over 80% of the population depends on mixed farming consisting of rain fed agriculture and livestock-based production. The major crop farming system in Eritrea is traditional smallscale farming with reliance on animal traction, which accounts for more than 95% of the cropped land. There is also irrigation based commercial farming of high value horticultural crops and some cereal production; these farms are highly localized in regions with water availability (Sati 2008).

The livestock sector contributes an estimated 63.1% of the total agricultural GDP and but only 6.6% of total GDP (FAO 2005). There are four types of livestock production systems distinguished in Eritrea: pastoralism, agropastoral, sedentary mixed farming and urban and peri-urban production. Pastoral and agropastoral systems account for most of the livestock and these production systems are associated with particular ethnic groups and regions in the country. Pastoral and agropastoral herds are dominated by camels and goats. The cattle that are herded are mainly local zebu types. Sedentary mixed farming is largely done by an ethnic group that is predominately agropastoralists, with the sedentary group having similar herd compositions; these animals also migrate seasonally, even if the farmers do not. Urban and peri-urban production is largely focused on dairy, but animal fattening and chicken farming also exists (Moehler and Leonard 2007). Stall fed dairy cattle are found in the Asmara region and are dominated by the imported Holstein breed (FAO/WFP 2005). Formal livestock censusing has not been done since 1978, but the estimated livestock populations for year 2012 were 1.9 million cattle, 2.1 million sheep, 4.7 million goats, 318,914 camels, 518,459 equines and 1.1 million poultry (EMoI 2012).

Though roughly divided into lowlands and highlands, when topography and rainfall variability is considered, Eritrea is divided into either four or six agroecological zones (Figures 1a and 1b). Only 10% of the landmass are highlands and yet these contain most of the agricultural production and 50 to 60% of the human population (SoE 2018). The lowlands are dominated by the extensive pastoral system though some commercial scale irrigation agriculture is occurring in the southern coastal lowland. Pastoral production has been constrained in recent years from frequent droughts coupled with limitation in cross-border transhumance during the conflict with Ethiopia. Dairy production and animal fattening production is constrained by access to feed (with access limited by cost and drought induced fodder shortages). Poultry production was increasing but feed shortages and import bans due to Avian flu slowed commercial growth in the early 2000s (Moehler and Leonard 2007).

Figure 1a: Four agroecological zones denominated. Image from FAO (2005).

Figure 1b: Six agroecological zones delimited. Image from Measho et al. (2018), credited to FAO (1997).



Key resources

EMoI (Eritrea Ministry of Information). 2012. *Livestock population and types of Eritrea*.

ICPALD (IGAD Centre For Pastoral Areas and Livestock Development). 2016. *The contribution of livestock to the national economy of Eritrea*. Policy Brief ICPALD 12/CLE/1/2016.

Masake, R., Oyoko, G., Too, R. and Onyango, D. 2015. *The contribution of livestock to the Eritrean economy*. Final report produced for IGAD Centre for Pastoral Areas and Livestock Development (ICPALD). (Available from http://www.au-ibar.org/component/jdownloads/finish/36-vet-gov/2722-the-contribution-of-livestock-to-the-somali-economy.) (Accessed 24 January 2020)

Food and nutrition security

Eritrea is a food insecure country. The 2019 report on world food security (FAO 2019.) did not have recent data for Eritrea, but the 2007 Africa Report by the World Bank lists Eritrea as the most food insecure in Africa (SoE 2012). It is listed as both a low-income nation and high import – high export dependent economy (FAO 2019). Local agricultural production can only meet 60% of the population's nutritional needs in good years; in poor years this can fall to 25% (SoE 2004). As crop production is largely rain fed and livestock production is predominantly based on extensive grazing, good years and bad years are largely dependent on climatic events. Frequent droughts and floods in the last decade have increased food insecurity vulnerability, particularly among the pastoral and agropastoral communities (FAO 2019).

Eritrea surveyed its population and assessed the food security situation in 2003. 66% of the population were classified as poor, with 37% being in the category of extreme poverty. Indicators of chronic undernutrition were found with 38% of children under 5 years being stunted, 15% wasted and 44% being underweight. This survey found rural to urban difference in poverty characteristics and found high number (30%) of female headed households. Though the Global Hunger Index 2018 reports that data is lacking for Eritrea, it notes that the stunting rate is likely as high as 52.8%. The highest number of poor live in the highlands, relaying on remittances and smallholder mixed crop-livestock agricultural production. The levels of extreme poverty are higher in the arid lowlands with reliance on pastoralism and agropastoralism. Poverty is considered the major risk for food insecurity in Eritrea but droughts and the recent conflict with Ethiopia are contributing factors (SoE 2004). With the peace agreement with Ethiopia the food insecurity situation has the potential to improve as labour for the agricultural sector will increase with the cessation of forced conscription, through drought and limited land arability will still affect food availability (von Grebmer et al. 2018).

Key resources

FAO/WFP. 2005. *Crop and food supply assessment mission to Eritrea*. Global Information and Early Warning System on Food and Agriculture Special Reports and Alerts (GIEWS) - ESC/Reports. (Avaialble from http://www.fao.org/docrep/007/j3959e/j3959e00.htm) (Accessed 28 January 2020)

Ghebru, B. and Mehari, T. (eds). 2007. *Innovative agricultural approaches of promoting food security in Eritrea: trends, challenges and opportunities for growth*. Proceedings of the workshop of the Association of Eritreans in Agricultural Sciences (AEAS). Asmara, Eritrea: Bern, Geographical Bernensia, 169.

Climate change

Climate change predictions were developed for Eritrea using the PRECIS Regional Climate Model to predict temperature and rainfall changes compared to the 1960–1990 baseline. Findings indicate mean surface temperature could increase in a range of 2.24°C to 3.39°C by 2080.

For rainfall, average daily rainfall increases by 0.4mm 0.5 mm per day under different future emissions scenarios, though the model signals are not consistent on rainfall prediction (from Beraki 2005). Four other GCM's projections reveal similar results for temperature increases, but with only an increase of 1–1.5°C for the average daily maximum temperature for the warmest month. Regarding changes in rainfall, the GCM's projection shows no change in annual precipitation, except for areas of the Red Sea zone where the projection shows a gain of 100–200 mm. None of the four models shows a reduction in rainfall (Ghebru et al. 2013). However, a review across all models has found that models of Eritrean rainfall have rainfall change projections from -30 to +62% per month (McSweeney et al. 2010).

Other projections for temperature and rainfall at 2030 and 2060 were reported in the National Communication (State of Eritrea 2012). Results from crop model projections revealed that fairly large areas of higher elevation, where temperatures are currently too cold for sorghum, should become available for sorghum production in the future. Projected higher rainfall may have influenced these changes in land suitability for rain fed sorghum farming (Ghebru et al. 2013).

Key resources

Ghebru, B., Araia, W., Ogbazghi, W., Gebreselassie, M. and Thomas, T.S. 2013. Eritrea. In: Waithaka, M., Nelson, G.C., Thomas, T.S. and Kyotalimye, M. (eds), *East African agriculture and climate change: A comprehensive analysis*. Washington, D.C.: International Food Policy Research Institute (IFPRI): 121–148.

McSweeney, C., New, M. and Lizcano, G. 2010. *UNDP climate change country profiles: Eritrea*. (Available from https://www.geog.ox.ac.uk/research/climate/projects/undp-cp/UNDP_reports/Eritrea/Eritrea.lowres.report.pdf) (Accessed 24 January 2020)

GHG emissions and livestock

Eritrea has submitted three national communications on its greenhouse gases emissions and action plans to the UNFCCC in 2001, 2012, 2018. The greenhouse gas inventory for 2000 placed the total national CO_2 emissions at 8,826 Gg, with the Land Use Change and Forestry (LUCF) category contributing 93% of this carbon. For methane, the total national emissions were 147 Gg. The agricultural sector contributed 90.5% of this CH_4 (133 Gg). Emissions from enteric fermentation alone accounted for 96% of this methane (Gg 128 CO_2e), with manure management contributing a further 5 Gg. N_2O emissions from manure management and fertilizer applications were found to be negligible in 1994. In contrast, in 2001, N_2O emissions were estimated at 1 Gg coming exclusively from the agricultural sector of agricultural soil source sub category (SoE 2001; SoE 2012; SoE 2018). Eritrea reports its emissions inventory based on Tier 1 methods for all source categories but is interested in moving toward Tier 2 (SoE 2012). Key source evaluations place the LUCF, Energy and agriculture sectors as the highest emitters.

Key resource
SoE (State of Eritrea). 2012. *Eritrea's second national communication under the United Nation Framework Convention on Climate Change (UNFCCC).* Asmara, Eritrea: The State of Eritrea Ministry of Land, Water and Environment.

Climate-smart livestock

In the 2012 NDC the mitigation analysis did not include the agricultural sector; resources for the assessment were limited and the biomass and fuel sectors were deemed a priority for management and mitigation. Thus, in the 2012 NDC the livestock sector only receives attention in regard to adaptation to climate change. Three major livestock sectors are discussed (pastoral, agropastoral and livestock traders). The report notes that traditional coping strategies for pastoral systems (movement and limitation of grazing hours) are failing. Pastoralists have already been adopting rainfed agricultural practices, but this has limited viability in the drier areas. The NDC proposes that these coping mechanisms 'should be replaced by planned strategies aimed to produce adequate feed and water for livestock production in their respective villages; reduction of livestock populations or destocking but increasing the value of individual animals which mean intensification of the pastoral system' (SoE 2012). In agropastoral, or mixed systems, the main strategies for coping are conservation of crop residues; enclosure of grazing land for use during dry season; selective feeding with priority given to oxen; selling of animals; and production and selling of firewood and charcoal. Targeted adaptation strategies for this sector are 'government support for establishing permanent water supply and improvement of perennial grasses and fodder species compounded with rotational grazing' (SoE 2012).

The final NDC agricultural adaption plan has more specificity in the goal setting but still lacks integration with any mitigation strategies. 'On the whole, climate change mitigation actions focus mainly on the following five sectors: (i) energy, (ii) industry, (iii) transport, (iv) forestry and (v) waste. The adaptation activities on the other hand will focus on (i) agriculture, (ii) marine resources, (iii) land (iv) water and (v) services such as education and health sectors' (SoE 2018). Land management activities, including enclosures and large livestock productivity increases (a goal of 75%), are listed adaptation goals (see table 1 and 2). One potential adaptation lists conservation agriculture, or CSA as a goal for 5% of the land.

In these reports land management and intensification are stressed as means to protect the environment as well as to increase resilience of the population by moving away from extensive pastoralism. These adaptations are put forward without emphasis on their concomitant mitigation potential. From this perspective, there is institutional opportunity for the expansion of comprehensive CSA approaches into Eritrean climate change planning.

CSA is mentioned in the framework by FAO for its program in Eritrea (FAO and SoE 2016). This framework sets three Priority outcomes: Priority 1, Sustainable natural resources management; Priority 2, Improved agriculture sector production, productivity and market access for enhanced food security and nutrition; and Priority 3, Preparedness and response to natural threats and improved resilience. CSA is proposed as part of the tool set for attaining both Priority 1 and Priority 2 above.

With the existing concern over pastoral production's vulnerability to climate shock, the low productivity of the herds and the need for rangeland and forest rehabilitation, Eritrea has high potential as a site for climate-smart approaches. Likely approaches would include forage and fodder supplementation, herd health support through veterinary and breeding services, rotational grazing and manure management techniques that are showing positive results in neighbouring country case studies.

Table 1: Adaptation strategies for the livestock subsector proposed in the 2012 NDC. Note the 2012 NDC lacked any mitigation strategies for the agricultural sector.

Livestock subsector	
2.2.1	Promote pastrue water supply
2.2.2	Promote seasonal forecasts, their production, dissemination, uptake and integration in model-based decision-making support systems
2.2.3	Promote livelihood diversification along with expanding access to finance, insurance, market and road networks to isolated communitiies
2.2.4	Intensify animal disease management through indigenous and scientific techiques
2.2.5	Promote illage level poultry farming
2.2.6	Develop a strategyto enhance livestock productivity and production
2.2.7	Support pastoralists to lead sedentary livellihood to access adequate social services
2.2.8	Promote dairies and support to sub-urban livestock production
2.2.9	Promote intensification of the pastroal system

Table 2: Adaptation strategies identified in the 2018 Final NDC. Note calls to increase livestock productivity, land enclosure, land management and rehabilitation.

Development and establishment of new enclosure areas over 750,000 ha;
Promotion of conservation agriculture (CSA) in 5% of the cultivable land;
Development and promotion of irrigation scheme by 170, 000 ha;
Afforestation program will cover over 36,000 ha;
Development of terrestrial and marine protected area of over 1.5 million ha;
Construction of 90 new dams and 120 ponds;
Safe drinking water supply will increase from 75% to 100%;
Desalination of sea water for domestic and economic sectors in 15 coastal towns and villages and 7 islands;
Wastewater treatment plant established to treat 3 million m3 of water/year;
Rehabilitations degraded land program for agriculture over 250,000 ha;
Livestock productivity increased by 75%;
Crop production of pulses will cover 25% of total cultivable land;
Sustainable Land Management practiced will be implemented in 15% of Eritrean the total land covered;
Prevalence of climate change related public health problems and diseases will be prevented and reduced by 90%.

Key resources

FAO and SoE (State of Eritrea). 2016. *Country programming framework for the state of Eritrea, 2017–2012*.

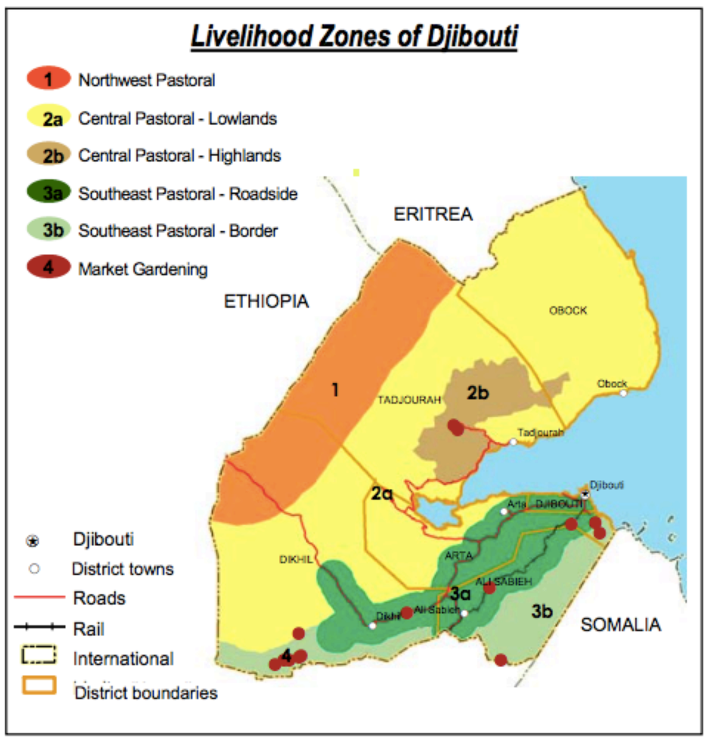
SoE (State of Eritrea). 2018. *Nationally Determined Contributions (NDC) Report to UNFCCC.*

Djibouti

Agricultural production and agroecological zones

The country is arid and as such arable land for crop production is highly limited (0.1% of the land) and pastoral systems predominate the agricultural sector. Fine grained analysis generates six livelihood zones; five pastoral zones distinguished mainly by slight rainfall variations, elevation and proximity to infrastructural improvements and one zone of market gardening (Figure 2). Domestic food production satisfies only 20% of the grain needs and 10% of the fruit and vegetable requirements of the population (CIA World Factbook 2018). The vast majority of the population lives in urban and peri-urban settings (reports vary between 65 to 78% urban)

Figure 2: Livelihood zones of Djibouti. Image from Lawrence and Mohiddin (2004).



An intriguing characteristic of the country is that agricultural production systems contribute only a fraction of the national GDP (with estimates of 2.4–5%) livestock production is the majority land use category (73.3% of the land); and livestock is the livelihood basis for one-third to half of the total population. For the rural population the dependence on livestock production systems rises to 90% (Brass and Leonard 2008). Moreover, these estimations of the role and value of livestock for Djibouti's economy are likely too low. ICPALD's reanalysis of the 2013 livestock statistics calculated a livestock contribution value of 15.79 million Djiboutian Franc (DJF) which is in contrast to the World Bank valuation of DJF6.9 million. These ICPALD values translate to 172% of the GDP of agriculture and 6.9% of the national GDP for the ICPALD study which more than doubles the World Bank percentiles (livestock at 75% of agricultural GDP and 3% of National GDP) (ICPALD 2016).

Djibouti's livestock production system is dominated by extensive nomadic or semi-extensive (semi-sedentary/semi-nomadic) pastoralism done at the subsistence level (Brass and Leonard 2008). In the extensive nomadic system animal movement can range over hundreds of kilometres moving across Djibouti, Eastern Ethiopia and Northern Somalia (Somaliland), highlighting the need for livestock policies and development initiatives to work at the regional not just country level. There has been a trend in the last decades towards semi-extensive production with sedentarization occurring around water points as governmental polices have encouraged the semi-sedentarization of pastoralists (Brass and Leonard 2008). There is only a very small amount of intensive, sedentary livestock production, mainly near urban areas and water sources. This is usually done in conjunction with market-oriented crop production.

Overall, livestock production is dominated by traditional approaches wherein animals fulfil multiple roles in the household economy. As such, sale of livestock accounts for only a small portion of livelihoods in the cash economy. Sales of livestock are infrequent (only 21% of livestock owning households sold animals in a six-month study period (WFP 2011b) and when sales occur they are often classified as "abnormal" sales, meaning they are done under duress or in response to emergent needs (WFP 2011b). The management of the livestock sector in Djibouti was characterized in 2004 as being constrained by feed shortages, overgrazing, the low genetic potential of animals, subsistence mentality, lack of trained manpower, lack of credit facilities for livestock owners and the absence of a commercialized export system (Simpkin 2004). Subsequently, a regional quarantine facility and certification process was developed which allowed for livestock exportation in 2006 and from 2006 to 2009 Djibouti was the sole regional supplier of livestock to Saudi Arabia (Majid 2010). The existence of the quarantine facility and the state-led verification process has meant that Djibouti has been drawing in more regional livestock trade, with animals from north eastern Ethiopia being processed through Djibouti (Majid 2010). Despite this urban trade centre, domestic sale of livestock lags as the locally produced animals cannot compete against the higher quality and cheaper imports from neighbouring countries (Lawrence and Mohiddin 2004).

Further development of the livestock sector in Djibouti is constrained by the arid environment. Feed and water resource shortages are predicted to be exacerbated by climate change. Frequent recent droughts are thought to have already reduced total livestock numbers in the country, but animal census data is limited. Researchers in 2004 calculated the national herd at 295,995 cattle; 464,359 sheep, 511,449 goats and 67,000 camels (Knips 2004). In the subsequent years, drought has decimated herds, in some areas it is estimated that goat herds were reduced by 24 percent and overall milk yields have fallen 45% from the 2003/2004 levels (FAO 2012).

Key resources

Lawrence, M. and Mohiddin, H. 2004. *Djibouti livelihood profiles*. Nairobi: Famine Early Warning System Network (FEWSNET) and United States Agency for International Development (USAID)

Brass, J.N. and Leonard, D.K. 2008. *The political economy of livestock policy: the case of Djibouti*. IGAD LPI Working Paper No. 02–08. IGAD Livestock Policy Initiative.
ICPALD (IGAD Center for Pastoral Areas & Livestock Development). 2016. L'apport de l'élevage dans l'économie de Djibouti. Policy Brief ICPALD 11/CLE/1/2016. ICPALD.

Food and nutrition security

Djibouti is a food insecure country despite having achieved nutritional advances over the last two decades. Countrywide PoU decreased from 60% in 1991 to 19.7% in 2015–2017 (UN-Stat. No date). Djibouti is a growing economy with developments being made in some sectors such that the World Bank now classifies the country as a lower-middle income country (LMIC). However, 16% of the population live below the international poverty line (USD 1.90 per day) and a national poverty calculation from World Bank data concluded that 21.1% of the population are living in extreme poverty (WFP 2019). The urban population of Djibouti has a generally higher food security status than the rural population; WFPs emergency food security assessments done for Djibouti in 2011 found that only 6.3% of the urban population were food insecure in contrast to the rural population at 42% being food insecure. A further 27% of the rural population were classified as moderately food insecure, which again is in contrast to the urban population at only 8.2% with borderline food insecurity (WFP 2011a; WFP 2011b).

Because of Djibouti's low agricultural production, 90% of food commodities need to be imported and food security in Djibouti's becomes very dependent on international commodity prices. Root causes of food insecurity in rural Djibouti appear to be structural poverty, characterized by very low productive and non-productive asset holding, low income levels and absence of job opportunities in rural areas. The lack of access to services such as education and health care aggravate this situation. In the last two years, this chronic situation has been exacerbated by high international food prices and very poor rainfalls (USAID 2018).

Key resources

WFP (World Food Programme). 2011a. *Urban EFSA*. Djibouti: OMDF Food Security Analysis Service, February 2011.

WFP (World Food Programme). 2011b. *EFSA*. Djibouti: OMDF Food Security Analysis Service, July 2011.

Climate change

A review of precipitation and temperatures in Djibouti over the years of 1966–2011 found that 'the 2007–2011 period has been the hottest five-year period ever recorded since 1966, 0.9C warmer than the long-term mean' (Ozer and Mahamoud 2013). Following this trend, recent climate projections for Djibouti from a suite of GCMs indicate that by 2050 Djibouti temperatures could increase between 0.6°C and 2.4°C. These models all predict sea level rise as well, with an average estimated increase of 0.2m. The climate models have less agreement on rainfall patterns, with some predicting more rainfall overall for the region and some predicting a drying trend (GFDRR 2011). Some models predict the shortening of the rainfall periods that support the lowland grazing zones. Other models predict variability in the September to February rains (GFDRR 2011). Ozer and Mahamoud's (2013) analysis of past weather extremes also points toward variability in rainfall, with the 2007–2011 period being the driest since 1980 and with a mean yearly rainfall deficit of 73% from the 30-year average.

Climate change will affect food and nutrition security directly through agricultural and livestock losses under extreme weather events, while the increased variability in weather will hinder capacity in agricultural planning. Vulnerabilities to various water resource stresses will increase from loss of seasonal water holes and from salinization of coastal waters with the rising sea levels (Wilby et al. 2010). Overall decreases in arable land is predicted and yield losses in crops of vegetables, fruit and fodder are expected (GFDRR 2011). Vulnerability to floods will also increase, even if a general drying trend continues, as people make informal settlements in the drying regions near waterways, but that are in fact still flood prone areas. Such increased vulnerabilities have high projected costs to economic growth (Kireyev 2018).

Key resources

GFDRR (Global Facility for Disaster Risk Recovery). 2011. *Vulnerability, risk reduction, and adaptation to climate change: Djibouti: Global Facility for Disaster Risk Recovery*. World Bank Group.

Kireyev, A. 2018. *Macro-fiscal implications of climate change: the case of Djibouti*. IMF Working Paper. International Monetary Fund.

GHG emissions and livestock

The government of Djibouti filed a NDC in 2001, and the final NDC in 2015. In the NDC it was determined that the agricultural sector accounted for 8% of the estimated total GHG emissions, with an emission of 206.37 Gg CO_2e (RoD 2001). The majority of the agriculture emission is from CH_4 with an estimated value of 205.8 Gg CO_2e; CH_4 accounts for 99.7% of the total agriculture emission. This suggests that enteric fermentation from livestock is the top agriculture emissions contributor. This emission inventory from Djibouti relied on Tier 1 calculations.

Key resources

RoD (Republic of Djibouti). 2001. *First national communication of the Republic of Djibouti to the United Nations Framework Convention on Climate Change (UNFCCC)*. Djibouti: RoD.

RoD (Republic of Djibouti). 2015. *Intended nationally determined contribution of the Republic of Djibouti*. Djibouti: RoD.

Climate-smart livestock

The 2015 NDC states that the adaptation and mitigation plans revolve around the counties five social priorities: 1. Reducing vulnerability to drought; 2. Protecting against rising sea levels; 3. Improving access to water; 4. Protecting biodiversity; and 5. Reinforcing the resilience of rural populations (RoD 2015). Social priority number five has relevance for potential deployments of CSA practices in the country.

Djibouti filed a National Adaptation Program of Action (NAPA) in 2006 with 8 priority projects (see Table 3). Despite the diversity of priorities in the NAPA, most attention in adaptation revolves around water. In the 2015 NDC, nine of the 15 funded programs and all four pending programs were water related. (See Table 4 for the non-water oriented adaptation programs). All the funded mitigation measures (eight in total) are for the energy and transportation sector. Only in the list of conditional mitigation measures are there landscape oriented options: fuel wood reduction; reforestation with silvapastoral practices; and reforestation with agroforestry.

As agriculture is only a small portion of the national economy this low coverage in the NDC is not surprising. However, livestock is a major land use category and for the rural areas, it is the major livelihood strategy. Hence social Priority 5 “reinforcing the resilience of rural populations” gives rise to the emphasis on supporting pastoralists (or at least some pastoralists) in maintaining pastoral livelihoods. Priority 4 from the NAPA (Table 3) establishes the need to support rangeland management in the northeast to facilitate the traditional extensive pastoral system. The report notes that if the pastoral system fails, no options exist for people other than migration to the urban areas where 75% of the national population already reside. Other land projects aim to decrease pasture degradation, rehabilitate fragile soils and plant communities, and encourage agropastoral systems. Attention is also given to the need to promote new livestock practices, in particular mixed crop-livestock opportunities to be integrated with irrigation developments (RoD 2006). Agropastoral promotion projects have included the development of irrigated farmland coupled with training programs for pastoral people transition to farming. One project has focused on creating field level microclimates through date palm perimeter plantings for the support of forage and vegetable production. An upward trend in numbers of agropastoral production systems since 2006 has been noted by the Agropastoral Association of Djibouti.[12]

Climate-smart livestock opportunities exist in the governmental interest in supporting continued pastoral practices and as well as in promoting agropastoral developments. Though extensive pastoral systems can be linked to high emissions rates, application of a number of mitigation technologies could decrease these emissions. Supporting the pastoral system is a CS practice in this context as other productivity options are so limited. Potential CS technologies are forage and fodder supplementation, manure management, animal health through veterinary services and breeding services for improved genetics. Other potential CS practices to aid in maintaining pastoral households and decreasing urban migration are government or NGO support for destocking and restocking campaigns and financial services such as index-based livestock insurance (which can aid in encouraging destocking in a climate risk situation).

These CS practices are possibilities in the agropastoral systems as well. Manure management through biogas production increases in feasibility with intensification. A cross production system synergy could be promoted by the government. Forage supplementation can be an important tool in reducing enteric gases as well as increasing the resilience of the pastoral households to stay in pastoralism. If adequate forage production is not possible in the targeted pastoral areas, institutional support could generate forage and fodder production as an economic strategy for the developing agropastoral systems (Table 4, project 1). Institutional support could include seed stock and price supports or facilitating markets and transportation.

[12] https://www.eaffu.org/djibouti/

Table 3: The eight priority projects set in the Djibouti 2006 NAPA. Clean pumping technologies, soil salinization and erosion stabilization were also identified in the adaption planning stage but did not make the priority list. Table adapted from RoK (2006).

1	Coastal zone protection against erosion and salinization
2	Forest protection and rehabilitation
3	Management and development of surface water resources
4	Rangeland management to reduce risk to extensive pastoralism in the north east
5	Promote mixed-crop livestock farming and integration with irrigation
6	Land regeneration with adapted forage species in Doda and Grand Bara areas
7	Restoration of marine protected areas and mangroves
8	Protecting the water supply of Djibouti City

Table 4: Funded adaptation projects for Djibouti with land-based components. Note 4, 5 and 6 include water access development along with land management. A 6th non water project deals with solar light provisioning. Table generated from RoD (2015).

1	Development of agropastoral perimeters as a strategy for Djibouti's poor rural communities. Data Palm planting for shade and microclimates supporting forage and vegetable growth
2	Support for adaptation to climate change among rural communities in mountainous regions
3	Pastoral system security project – PSSP/SHARE (2014) – support pastoral communities, water access, animal health, livelihood diversification, institutional capacity building for state services provisioning
4	Implementing Adaptation Technologies in the Fragile Ecosystems of the Tadjourah and Hanlé Plains
5	Support project for the resilience of rural populations

Somalia

Introduction: Somalia and Somaliland

Somalia has long struggled to quell its civil unrest and internal violence. The failures of the government in Mogadishu to fulfil its functions led many to label Somalia a failed state. In 1991 the five northern regions of Somalia declared themselves the sovereign state of Somaliland (see Figure 3). Somaliland has since then established its own democratic government and its own currency; internally it operates as its own country. However, for a variety of political reasons, Somaliland is still not recognized as a sovereign country by the broader international community. This lack of international political recognition has implications for how international businesses and aid organizations must work and report on the region. Many international organizations do not disaggregate their data on the region into Somalia and Somaliland. This review first presents Somalia, which includes some information on the Somaliland region and then the review will also present a section on Somaliland.

Figure 3: Map showing the division of Somalia and Somaliland. From BBC
https://www.bbc.com/news/world-africa-14094503

Agricultural production and agroecological zones

Somalia is often referenced merely as arid but fine detail AEZ mapping has identified 32 AEZs (Figure 4) Similarly, the major livelihood strategies are broadly categorized as pastoralists, agropastoralists, fishing and coastal communities and urban. A fifth "livelihood" category, internally displaced persons (IDPs), is sometimes listed and is an outcome of the long running civil war. Livelihood distribution and the national economy have been altered by this long running conflict. The population of Somalia was predominantly rural and involved in pastoral and agropastoral production in the 1990s (SACB 2004). With the conflict, demographic change occurred such that the most recent population survey found that almost half the population (42%) are now urban, 23% are settled rural, 9% are IDPs and only 26% nomadic pastoral (UNFPA 2014). With the marginal increases in stability after 2010 more research on the country is occurring and the livelihood strategy mapping has become more fine-grained (Figure 5, from FSNAU 2015).

Figure 4: Somalia can be divided into 32 agroecological zones (Veenma 2007).

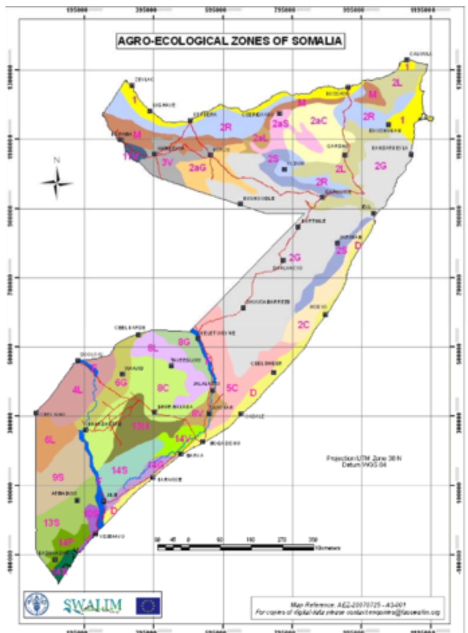
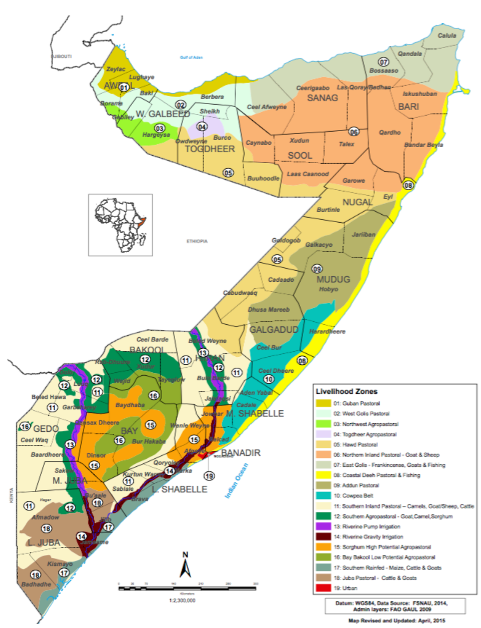


Figure 5: Livelihood zones map (FSNAU 2015)



The most recent World Bank and IMF estimates place the value of livestock and livestock products as 61% of the GDP, though quality of these estimates is questioned. What is known is that during the civil war the livestock sector had likely expanded from its measured mid 1980s values with corresponding decreases in the crop sector due to conflict passed land tenure instability (FAO/WB 2018). Somalia is the world leader in camel milk production and has the world's largest national herd of camels (around 7 million animals). The milk production sector of Somalia has had camel based dairy operations with as many as 150 dairy camels. Camel milk production is for local consumption as camel milk is generally preferred over cow milk in the Somali population. Overall livestock and crop agroprocessing remains limited, despite the relative importance of agricultural sector in Somalia' international export trade (FAO/WB 2018). The export trade is dominated by live animal export, which brought in 79% of national export earnings in 2015 (FAO/WB 2018). This 2015 trade was calculated to be over 5 million head of livestock, though 30 to 40% of these animals are thought to be coming from Ethiopia and Kenya (USAID 2015). Formal surveys of Somalia livestock numbers are lacking. Estimates have been done based on historic numbers and expected growth rates putting national herd numbers (minus Somaliland) at 4.7 million cattle, 13 million sheep 17.8 million goats and 7 million camels for 2013 (Too et al. 2015). Recent analytical work by the FASNU for the Drought Impact Needs Assessment put the national herd totals at 3.9 million cattle, 13.6 million sheep, 28.7 million goats and 6.6 million camels (reported in FAO/WB 2018). However, it has been noted that Somalia 'is hobbled by a severe lack of basic economic and social statistics data.' The few statistics available are outdated, inconsistent and/or unreliable. Studies of agriculture are often localized, isolated, and fragmented. They 'lack conceptual and methodological rigor and produce few robust findings that can inform large and/or long-term investment decisions' (FAO/WB 2018). As such, national herd size estimates are likely very inaccurate. What is known and has remained consistent is that Somalia has long been the world's leader in camel based production, in particular in the importance of the camel milk sector to local subsistence and the Somali economy. Milk was calculated as 81% of gross value of the entire agricultural sector, and it was calculated that camel milk consumption is more than double the amount from cattle and small ruminants combined (data from 2013, consumption per caput, camel milk 223.6l, cattle 54.2l and shoats 51.2l) (ICPALD 2016).

Key resources

Venema, J.H. 2007. *Land resources assessment of Somalia*. Technical Project Report L-12. Nairobi, Kenya: FAO-SWALIM.

FAO and World Bank. 2018. *Somalia: Rebuilding Resilient and Sustainable Agriculture*. Somalia Country Economic Memorandum Volume 1. World Bank and the Food and Agriculture Organization of the United Nations. ISBN: 978-92-5-130420-4.

Too, R., Masake, R., Oyoko, G. and Onyango, D. 2015. *The Contribution of livestock to the Somali economy*. Final Report Produced for IGAD Centre for Pastoral Areas and Livestock Development (ICPALD) Dec 2015.

ICPALD (IGAD Centre for Pastoral Areas and Livestock Development). 2016. *The Contribution of Livestock to the Somalia Economy*. ICPALD Policy Brief 10/CLE/1/2016.

Food and nutrition security

Somalia is a food insecure country. Somalia is listed as both a low-income nation and high import/high export dependent economy (FAO 2019). Agricultural production only meets 22% of the cereal needs and overall agricultural imports have increased since the 1980s (FAO 2018). The 2019 report on world food security (FAO 2018) did not have recent data for Somalia but the UNDP (2012) classifies 80% of the Somalia population as poor. Similarly, the recently conducted Somalia High Frequency Survey found that 52% live below the international poverty line of USD1.9 per day (data for 2011 in FGoS 2018b). Though enough data was lacking for a full GHI calculation for Somalia, the known statistics point to some grim conditions. For 2015–2017 the PoU for Somali was estimated to be 50.6%, which is the 2nd highest for the 119 countries in the GHI 2018 report; the child mortality rate for Somali was at 13.3%, the highest for all 119 countries in the report (von Grebmer et al. 2018).

The long running war has created many internally displaced persons, increased the number of female-headed households and has overall decreased the levels of agricultural production in the country. These situations have increased vulnerability to food insecurity in the country. The frequent recent droughts have exacerbated this food insecurity situation. The conflict and drought induced famine of 2011 was followed by the 2016/2017 drought which put more than half of the Somalia population in need of humanitarian assistance (FGoS 2018a). A recent food and nutrition security surveillance project calculated acute malnutrition in the country at 16% for the surveyed 2001–2009 period and found overall micronutrient deficiencies across the population (WHO et al. 2016). Historically the rural farmers, livestock keepers and fisherman were the most food insecure, but rapid urbanization during the conflict period and drought driven high food costs have seen a rise in food insecurity among all livelihood sectors and has produced higher levels of poverty now in the urban areas than in the rural areas (FGoS 2018b).

Key resource

WHO, UNICEF, WFP and FAO/FSNAU. *2016 Somalia Nutrition Strategy 2011–2013*.

Climate change

Somalia has a variable temperature and rainfall pattern with both strong seasonality and large interannual variability. The yearly 4 season cycle of rainfall is largely influenced by the ITCZ while the cycles of droughts that have occurred throughout the 1980s and 2000s are found to be driven by the El Niño Southern Oscillation (ENSO). There is uniformity in climate change models for generalized trends in both increased temperatures and increased rainfall for the country. Temperature increases will be higher for the southern lowlands than for the northern (Somaliland) highlands and the overall temperature increases could be between 3°C to 4°C by 2020. Similarly, the models project rainfall increases generally in the range of 2–3% increases up to 2080 (all generalizations from FGoS 2013). More recent modelling run by Ogallo et al. (2018) for southern Somalia again shows increases in minimum and maximum temperatures for all seasons but found that rainfall could possibly decrease in the period up to 2030.

In all models the distribution of rains is not uniform over the seasons and over the landscape (FGoS 2013). In short, seasonable variability in rainfall is expected to increase, and concomitantly both drought and flooding risks will increase. The long coastline of Somalia and its jutting position on the HOA make a large portion of the land at risk from climate change conditions of more frequent extreme tropical storms and rising sea levels which can salinize inland water resources.

Beyond the generalized climate change risks to livestock (see regional discussion) social conflict is also likely to increase with drought. An analysis run on conflict incidents, drought conditions and livestock costs in Somalia found strong correlations that with increased temperatures, livestock prices decrease, and the number of conflict incidents increase and posited that the increased drought frequencies under climate change will exacerbate the social unrest and increase conflict potential in the Somalia region (Maystadt et al. 2013).

Key resources

FGoS (Federal Government of Somalia). 2013. *Somalia national adaptation programme of action on climate change*.

Ogallo, L.A., Philip, O., Ouma, G. and Wayumba, G. 2018. Climate change projections and the associated potential impacts for Somalia. *American Journal of Climate Change* 7: 153–170)

GHG emissions and livestock

Somali filed an INDC in 2015. However national GHG emissions calculations have not been done by the state and as such estimates of livestock contribution to the total GHG is unavailable. Utilizing 2010 livestock estimates (7.76 million cattle; 7.3 million camels; 36.8 million sheep and goats) and IPCC 2006 Tier 1 emission factors, GHG emissions from Somalia livestock production is derived to have been 6.17 Mt CO_2e from cattle, 9.69 Mt CO_2e from camels, and 6.25 Mt CO_2e from small ruminants in 2010. In this scenario camels contribute 42% to the total livestock sector emissions.

Key resource

FGoS (Federal Government of Somalia). 2015. *Somalia's intended nationally determined contributions (INDCs)*. Mogadishu, Somalia: State Minister for Environment, Office of the Prime Minister and Line Ministries and Ministry of Planning, Federal Government of Somalia.

Climate-smart livestock

Somalia's livestock sector faces many challenges. Though political stability is evolving, governance institutions are limited, primary infrastructure is damaged or lacking, and large population numbers are still internally displaced by the cycles of violence. The frequent occurrence of extreme drought both exacerbates the social challenges above and directly effects the functioning, and viability, of the Somalia agricultural sector.

The NAPA for Somalia[13] (2013) identifies three main program areas: Sustainable land management; water resource management; and disaster management. The intersection of the NAPA priorities with livestock management are multifaceted. Disaster management includes fodder storage facilities to aid in offsetting livestock loss in drought events. The water resources management includes rehabilitation of traditional water technologies as well as the development of large-scale livestock watering points and boreholes. The sustainable land management program aims to decrease deforestation and rangeland loss. The combination of drought and conflict have driven increases in charcoal production; this production is increasing deforestation and exacerbates the degradation of the Somali rangelands through the removal of the shading acacia trees. The main direct livestock-oriented program in the NAPA is for improved rangeland management and 'the enforcement of a system for rotational grazing' (FGoS 2013). The adaptation plans for livestock proposed in the NAPA are geared toward direct animal support measures (fodder, health services, herd management strategies), livelihood diversification strategies, and value chain augmentation (see Figure 6).

The government of Somalia has been strengthening its institutional capacities and in 2018 the country economic memorandum "Rebuilding Resilient and Sustainable Agriculture in Somalia" was released (World Bank and FAO 2018). This document provides a deep review of the agricultural sector, including the livestock subsector. Recommended actions in the livestock sector mirror aspects of the NAPA, i.e. diversification of livelihoods, animal health measures, and herd and rangeland management (Textbox 1). Overall, this document stresses the need for synergistic development approaches as adaptation of the agricultural sector is occurring at the same time as the reestablishment of a functioning agricultural sector and governance institutions. Therefore, many opportunities exist for utilization of the CSA approach. In fact, the World Bank and FAO report states that CSA approaches are critical:

> Climate change: full implementation of Somalia's well though out indicative action plan is needed to foster the adaptation of its agricultural systems for improved climate resilience. This should focus on, inter alia, supporting adoption and scale up of climate- smart agriculture practices and innovations. (World Bank and FAO 2018)

However, despite this acknowledgement of the value of a CSA approach, the report treats CSA as a tool for Development strategizing in the crop sector only. This oversite likely arises out of the preponderance of literature that conflates CSA with conservation agriculture, as well as the fact that CSA approaches worldwide have so far been dominated by applications to crop systems[14]. With the proposed goals of livelihood support and transformations, value chain addition, and market development, there will be many opportunities for explicitly deploying climate-smart livestock strategies. Effort should be placed on providing documentation on climate-smart livestock strategies and case studies to the relevant Somalia governance institutions.

[13] The range of proposed programmes in this NAPA covers Somalia, Puntland and Somaliland.
[14] This constrained and limited interpretation of CSA can also be an outcome of the World Bank's lead on developing this report. See Taylor (2017) for a critical review of the CSA approach as operationalized by the World Bank.

Textbox 1: Main conclusions on Livestock system needs in the 2018 "Rebuilding Resilient and Sustainable Agriculture in Somalia" report (World Bank and FAO 2018).

> Livestock: A top priority of public policy and assistance should be building capacity along the entire value chain to cope with animal disease threats, coupled with open and regular dialogue with importing countries to review and update sanitary standards and other import requirements.Other priorities include promoting innovative breeding and good husbandry practices and strengthening rangeland use policies, planning, and enforcement, with community participation. Support is recommended for integrated production systems, to leverage the interlinkages between crop agriculture and peri-urban livestock rearing systems for an expanded and more efficient feed supply chain and the promotion of more value addition and diversification opportunities. Rangeland use policies, planning, and enforcement, especially regarding private enclosures, also need strengthening. With strong promotion of private sector–led value addition and the processing of animal products, output of livestock products could easily exceed the modest official targets.

As the urban centers of Somalia are now evidencing higher poverty and food insecurity than rural areas, some measures to decrease urban migration from failed pastoralists is needed. Support for transition to agropastoral or mixed crop-livestock systems should be pursued in areas where crop production is viable. In other areas extensive pastoralism might be the only livelihood option. In these cases, likely climate-smart livestock practices are forage and fodder supplementation, manure management, animal health through veterinary services, and breeding services for improved genetics. Other potential CS practices to aid in maintaining pastoral households and decreasing urban migration are government or NGO support for destocking and restocking campaigns and financial services such as index-based livestock insurance. CS practices for agropastoral systems and mixed systems include those above, but manure management through biogas production increases in feasibility with intensification. Somalia's vast camel herd and the social popularity of camel milk over cattle milk provides opportunities for the development of original camel-based climate-smart livestock strategies.

Figure 6: Proposed adaptation measures for livestock systems in the 2013 National Adaptation Programme of Action to Climate Change. Image copied from FGoS (2013).

Animal Husbandry, Livestock and Rangelands	**1. Land management with emphasis on preventing deforestation, planting new trees, establishing regulations for rotational grazing and protection and supervision of grazing areas. This program should be administered by Ministry of Environment, District Officials and Traditional Elders and Leaders of the communities** **2. Provision of veterinary services by the government, ensuring access to remote rural areas and establishing diagnostic labs** **3. Support pastoralists in becoming agro-pastoralists or livestock farmers, whereby their livelihoods are diversified. This should include support for the cultivation of fodder crops.** **4. Control the export of female livestock due to the negative impacts on the sector** **5. Cultivation of drought resistant fodder crops** **6. Enhance livestock-based livelihoods through support to small-scale industries (hides, tanning, milk) and training in marketing of animal products (cheeses and yogurt)** **7. Provide funding and mechanism for research into animal health** **8. Establishment of livestock associations and cooperatives and support to local NGOs working in the sector**

Key resources

FGoS (Federal Government of Somalia). 2013. *Somalia national adaptation programme of action on climate change*. Mogadishu, Somalia: FGoS.

World Bank and FAO. 2018. *Somalia: rebuilding resilient and sustainable agriculture*. Somalia Country Economic Memorandum Volume 1. International Bank Reconstruction and Development/The World Bank and the Food and Agriculture Organization of the United Nations ISBN: 978-92-5-130420-4.

Somaliland

Agricultural production and agroecological zones

Somaliland landmass is glossed as arid, with 8 of the 10 mapped AEZs being arid or desert (Figure 7a). Land use is dominated by pastoral and agropastoral production (Figure 7b). Only 3% of the land is farmed, though studies suggest up to 7% more of the land could be suitable for agriculture (MoNPD 2011a). Mixed crop-livestock production is mostly in the highlands and in the peri-urban area around Hargeisa. Though historically a rural based population, urbanization of the population has occurred with the growth of the capital Hargeisa and the port city of Berbera. Now, 53% of the population is urban, and only 11% rural (settled), and 34% of the population is nomadic. Unlike Somalia, Somaliland does not have a large population of conflict displaced people, only 2% of the people are internaly displaced persons (INDs) (all population statistics from MoNPD 2017). The increase in peri-urban settlement has led to increased enclosures of the flood areas of the seasonal waterways, which are traditional rich fodder zones. These enclosures exacerbate tensions between clans as transhumant households become excluded from traditional migration zones (Pfeifer et al. 2018).

Figure 7a: Map of Somaliland agroecological zones. From MoNPD 2001b, Data originally from FAO-SWALIM.

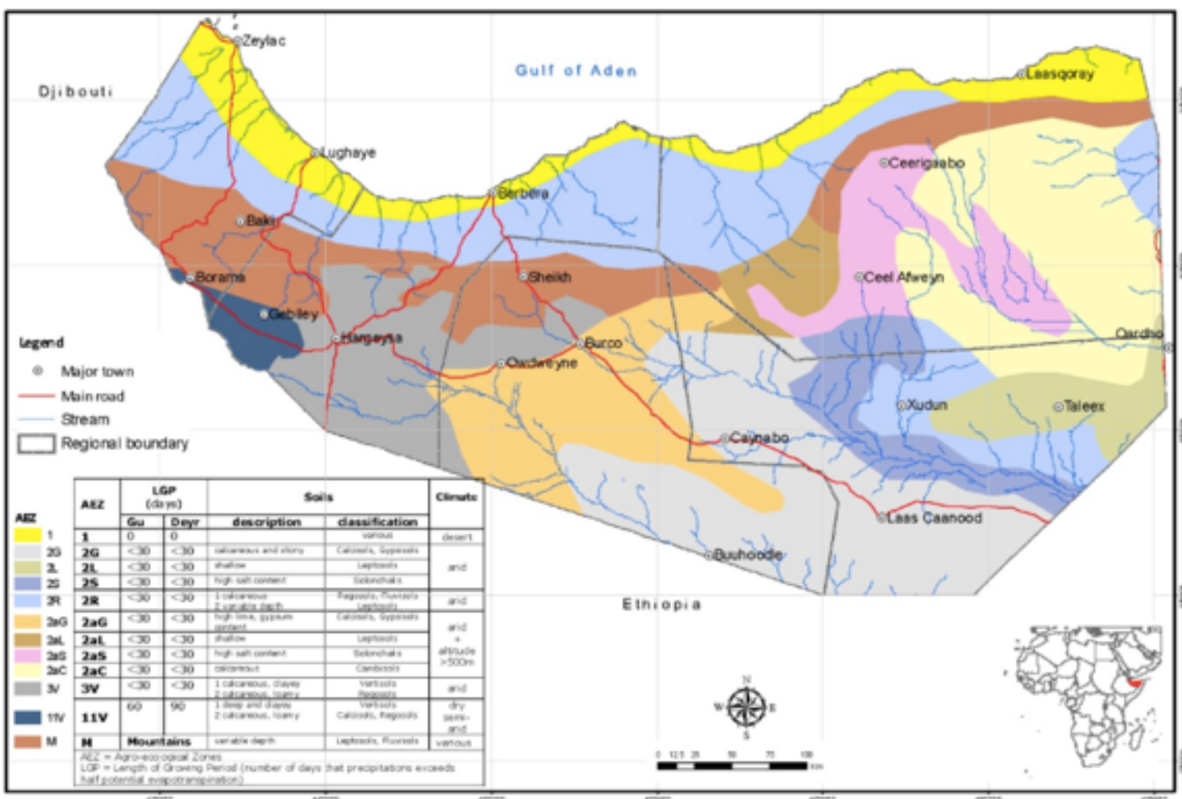
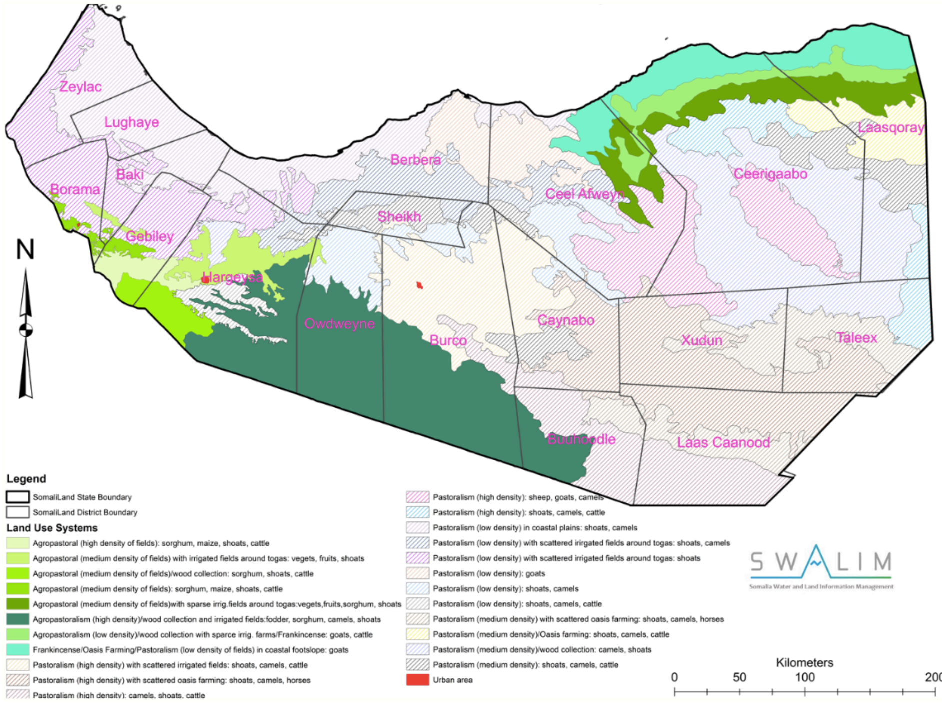


Figure 7b: Map of Somaliland livelihood zones (Pfeifer et al. 2018).



Livestock are frequently referenced as being the "backbone" of Somaliland as they play a historic role in the cultural identity of the Somali pastoral people and continue to be the dominant livelihood strategy for the rural population. The livestock sector is the single largest sector of the formal GDP, but this is calculated as only 28.4%, despite being the livelihood basis of 60 to 65% of the total population. The largest portion of this GDP value of livestock comes from the export market for live animals (which is more than double than the reported internal slaughter rate). However, the GDP valuation of the livestock sector is likely undervaluing the non-monetized values of livestock in livelihoods (ICPALD 2016). The dairy sector is dominated by smallholder production, as of 2010 there was only one modern 200 head, dairy farm. Poultry production in the country is very limited, and like the dairy sector relies on imports to meet local product demand. Other agricultural production provides small percentages of the country GDP: crops 7%, forestry 4.6% and fisheries 0.3% (all GDP statistics in this section from MoNPD 2017).

A formal livestock census has not been conducted since 1975. Based on standardized reproduction rates, the government has estimated population numbers to be about 1.646 million camels, 8.072 million goats, 8.458 million sheep and only 394,000 cattle (MoNPD 2011a). These numbers were calculated for 2009. The droughts that have occurred since 2015 have substantially reduced livestock numbers.

Key resources

MoNPD (Ministry of National Planning and Development). 2011. *Somaliland food and water security strategy*. Somaliland Vision 2030.

MoNPD (Ministry of National Planning and Development). 2017. *The National Development Plan II, 2017–2022*. Hargeisa, Somaliland.

Food and nutrition security

Somaliland is a food insecure country. International poverty metrics place Somaliland at 72% poverty (FAO/WB 2018) but more specific measures and indicators for Somaliland are difficult to ascertain as many international organizations continue to group Somaliland in with Somalia, as in the 2019 state of the world nutrition report (FAO 2019). Malnutrition is a constant concern for the country, put succinctly in a government report, 'the malnutrition situation in Somaliland stays between serious to very critical, and at best on alert category' (MoNPD 2011b). Somaliland is reliant on food imports, with a calculated self-sufficiency ratio for 2000–2011 of merely 11.1% (MoNPD 2011b). Drought conditions decrease both the rain-fed sorghum and maize production and decrease forage for livestock. Subsequent decreases in livestock condition, and drought induced livestock death push food insecure pastoral households into food crisis conditions. Such dynamics were seen in the El Niño induced rainfall shortages of 2015 and 2016.

Key resource

MoNPD (Ministry of National Planning and Development). 2011b. *Somaliland food and water security strategy*. Somaliland Vision 2030.

Climate change

Few climate models deal exclusively with Somaliland, but rather it is nested into the models of Somalia. Climate change planning for Somaliland explicitly point to the risk of both more drought and more floods (UNDP 2017). 18 out of 21 climate models predict overall precipitation increases for the GHA and all models predict increased temperatures (IPCC 2007). Somaliland is vulnerable to flooding in the two river basins that receive waters from the highlands of Ethiopia; the potential for flooding increases with the predicted higher intensity rain events in the highlands. Analysis of past weather station data for Somaliland indicates that droughts have intensified in terms of their frequency, severity and coverage over the last two decades (Abdulkadir 2017). Regional models also suggest increased interannual variability of the onset and duration of the rains for the region (MoFAN 2018). Variation in seasonable predictability is already being experienced in Somaliland, with forage availability directly affecting pastoral livelihoods through loss in animal condition and numbers; the pastoralist also report they are already seeing changes in animal behaviour in mating and parturition timings (Hartmann et al. 2010).

Key resources

MoFAN (Ministry of Foreign Affairs of the Netherlands). 2018. *Climate change profile: greater Horn of Africa*. The Hague, Netherlands: MoFAN.

Muchiri, P.W. 2007. *Climate of Somalia*. Technical Report No W-01. Nairobi, Kenya: FAO-SWALIM.

GHG emissions and livestock

Information is lacking on Somaliland GHG emissions as Somaliland has not published a NDC nor have emissions estimates been made for the country by international organizations. The national development plan for 2017–2019 only mentions GHG once, and that is to note that data compilation needs to be done (MoNPD 2017).

Climate-smart livestock

Somaliland published its Vision 2030 Food and Water Security Strategy in 2011. This details the governmental institutional vision for the agriculture and water sectors. The agricultural vision includes programs for crops, livestock and fisheries. The development goals set in this vision provide many opportunities for the implementation of CSA approaches in general, and climate smart livestock development in particular. In the report, the goals for the Livestock sector are listed under the two themes of “Promote Livestock Production” and “Promote Animal Health" (see Table 5). The themes of direct animal health augmentation through disease management (6) and forage supplementation (4) overlap with known climate-smart livestock practices. Range rehabilitation (5), infrastructural development and market access (1), and livelihood augmentation (2) all fit within climate-smart livestock frameworks for improving productivity of livestock systems as adaptations for climate change resilience. Moreover, the crop sector development goals also have implications for climate-smart livestock approaches: the vision includes goals of appropriate technologies for soil fertility; encouraging draught power utilization through training and facilitating access to animal drawn farm implements; and promoting fodder production.

The National Development Plan (MoNPD 2017) highlights the importance of the livestock sector on its international trade profile, and the reinstitution of an import ban by Saudi Arabia has had quick and deep impacts on national revenue streams. As such promoting livestock health management and services delivery (Points 6–10 in Table 5) are seen as high priority. Though the role of livestock in baseline subsistence is acknowledged the emphasis in the NDP national is on market oriented and value-added production. The NDP briefly mentions a trend from pastoral to agropastoral production but does not explicitly have targeted plans for any remaining existing extensive pastoral production. This generalized interest and emphasis on intensification and market-oriented production can be seen in the stakeholder visions of the future that were generated during a recent participatory research project in Somaliland (Pfeifer et al. 2018). In each of the three respondent groups livestock intensification was part of their projected 2030 vision. However, it must be noted that this intensification was *not* considered as opposed to the continuation of nomadic life practices in the country. See the story from one of the focus groups:

> Participants envisioned a change from the nomadic system to a zero-grazing system. Groups of people would be given land and the water access needed for this change. The enforcement of land policies and regulation would make this change possible… Also, there would be plenty of dairy farms which would contribute to improved nutrition for all. These farms would be established in a way to not hamper pastoral migration routes and managed in a way to maintain natural resources. This would be made possible by the development of land reform policies based on regional information. Land would be demarcated according to clan borders. Each clan would be mobilized to create dams so that it could utilize the natural resource without conflicts. [Pfeifer et al. 2018, emphasis added]

In this scenario building, participants envisioned both zero grazing development and the continuation of the nomadic pastoral system. These compelling visions speak to the climate-smart livestock needs and possibilities for Somaliland. Policy interest already exists to integrate livestock into agricultural practice (draught animals), awareness exists for the need to support rangeland management for environmental sustainability, and institutional backing is already there for improving livestock health services. A climate-smart livestock approach can aid in bringing these elements together. Promotion of peri-urban mixed crop-livestock systems should be pursued as well as dairy intensification strategies. Extant pastoral systems can be supported through health and herd management services to increase productivity; fodder supplementation training and the development of a national emergency reserve could support both pastoral herd health as well as providing market security for agriculturalists.

Table 5: Development Goals for the Livestock sector as listed in the Somaliland Food and Water Security Strategy: Somaliland Vision 2030. 2011. Table generated from report data.

Promote livestock production	
1	Improve rural access to infrastructure, communication and market opportunities
2	Develop sustainable livestock production techniques and technologies through research and development, training and extension.
3	Develop and promote technologies for adding value to animal products such as meat, milk, ghee, hides, skins and bones for local consumption and export.
4	Create range reserves and fodder banks for dry seasons
5	Develop rangeland and pasture rehabilitation programs
Promote animal health	
6	Train livestock herders and extension workers in animal pest and disease control
7	Promote research on livestock health and diseases
8	Build laboratories for vaccine production
9	Establish quarantine and holding grounds to ensure exported animals meet international health standards
10	Carry out quality control screening on veterinary drug imports

Key resources

Pfeifer, C., Crane, T.A., Mugunieri, L., Farah, A.A., Dubad, A.B. et al. 2018. *The dynamics of natural resources in Somaliland —Implications for livestock production*. ILRI Discussion Paper 35. Nairobi, Kenya: ILRI.

MoNPD (Ministry of National Planning and Development). 2011b. *Somaliland food and water security strategy*. Somaliland Vision 2030.

Ethiopia

Agricultural production and agroecological zones

Agricultural production system classification in Ethiopia has been done utilizing both broad and narrow levels of specification. The five classifications of highland mixed farming, lowland mixed agriculture, pastoral system, shifting cultivation and commercial agriculture were identified in the annual report of the Ethiopian economy (Degefe and Nega 2000). These broad classifications are still utilized as the basis for recent FAO analyses of farming systems in Ethiopia (see Figure 8). These reports highlight that most of the agricultural production in Ethiopia is through smallholder agriculture which accounts for 95% of the total agricultural output (Njeru et al. 2016). Moreover, 80% of this agricultural production is rainfall dependent (Mohamed 2017).

Figure 8: Agricultural production systems as classified by FAO (Njeru et al. 2016)

Farming system	Smallholder agriculture	Commercial agriculture
Highland mixed agriculture	95% of the annual gross total agricultural output of the country	Commercial farms contribute to only 5% of gross total agricultural output
Lowland mixed agriculture		
Pastoral and agropastoral farming	Average farm size ranging from 0.5-2 hectares	
Shifting cultivation		

In contrast to this rough division of production types, the Ministry of Agriculture and Rural Development developed an 18 agroecological zone classification system based on moisture and temperature variations and highlighting key crops (Figure 9). This zone classification is replicated frequently (for example see Deressa et al. 2010). Other research practices have generated an eight agroecological zone classification, but with subsequent 16 zone farm systems designations (see Amede et al. 2017) (see Figures 10a and 10b).

Figure 9: Agroecological zone classification with 18 regions. (From Tadesse et al. 2006, original Natural Resource Management and Regulatory Department, Ministry of Agriculture and Rural Development Ethiopia).

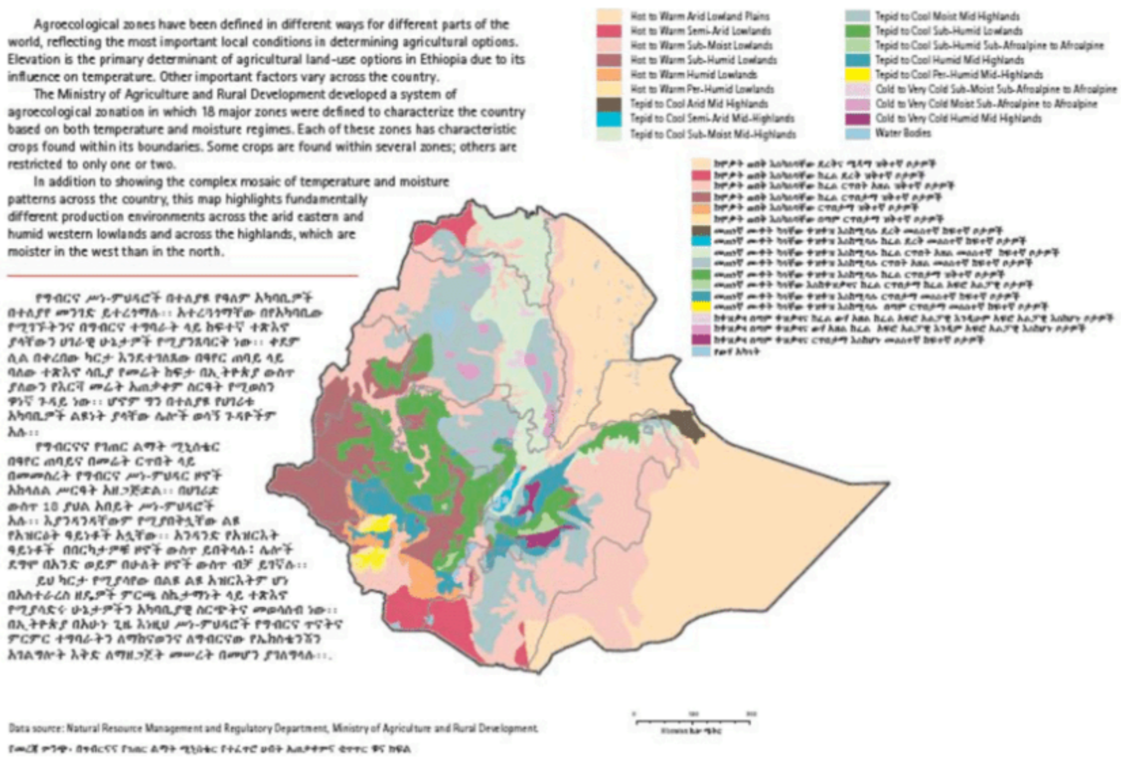


Figure 10a: Eight agroecological zones (Amede et al. 2017)

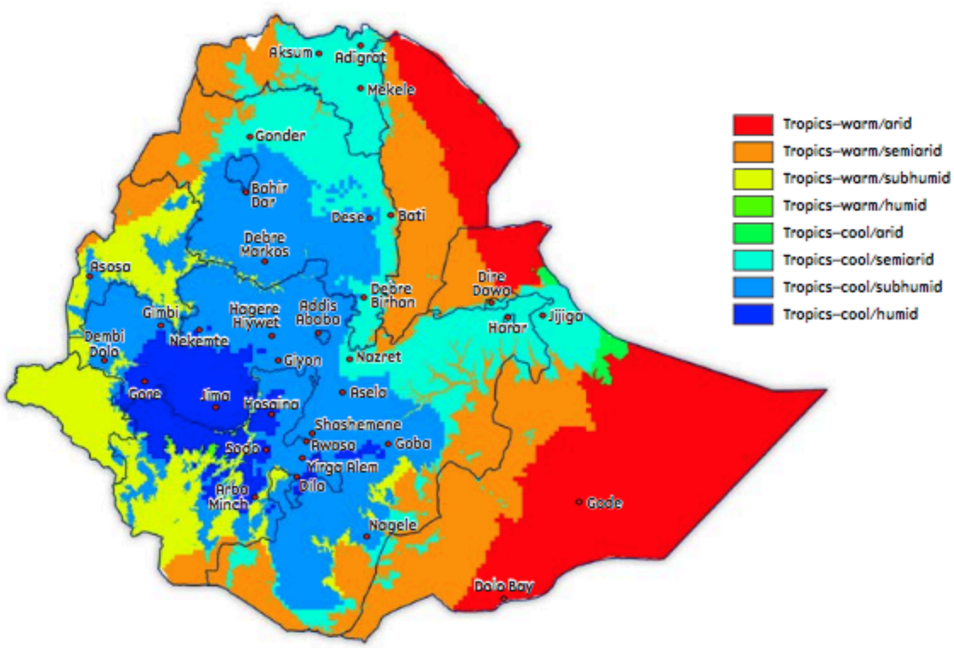
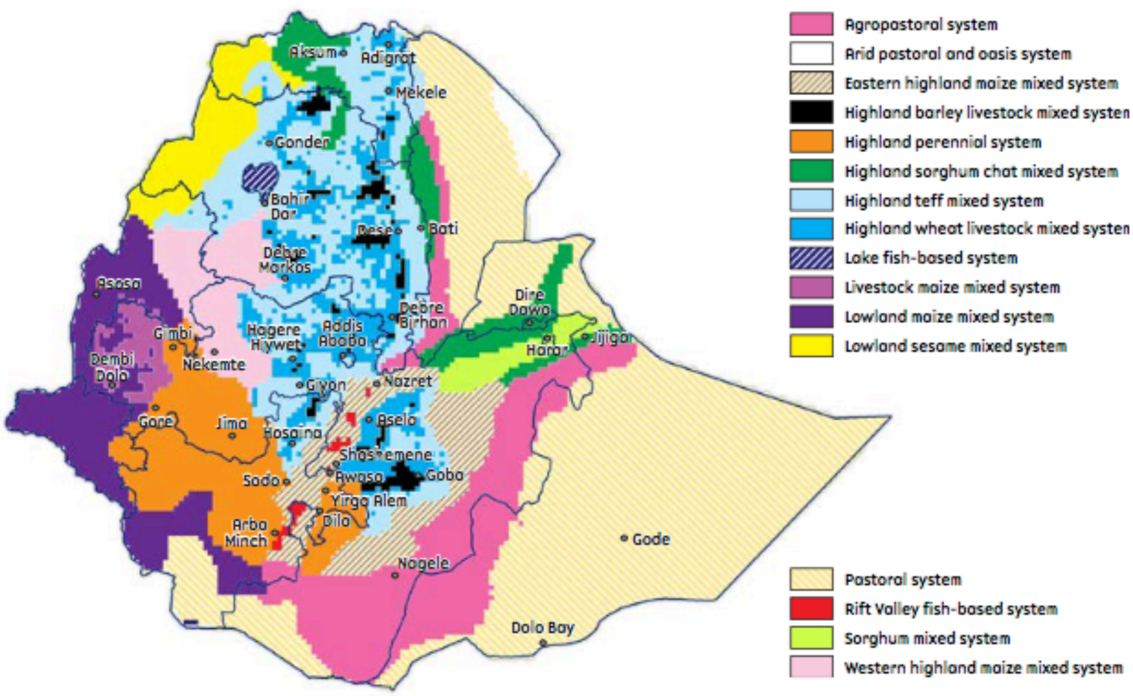


Figure 10b: Sixteen Farming Systems (Amede et al. 2017)



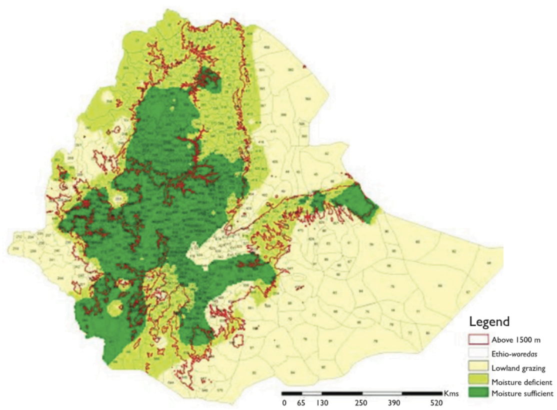
It is noted in these reports that though there is diversity in the crop types produced throughout Ethiopia, the livestock sector is a key element in household livelihood in most of these zones. Agricultural production supports 80 to 85% of national employment and accounts for 42% of the GDP, of which the livestock sector alone is 19% of the GDP (2012 Ministry statistics, reported in Shapiro et al. 2017). Ethiopia is considered to have one of the largest livestock populations in Africa (Njeru et al. 2016) and notably, 63% of this livestock is to be found within mixed crop-livestock systems and only 36% in the pastoral and agropastoral systems (FAO and NZ 2017).

Cattle are the highest percentage of livestock in the mixed rainfall sufficient zone (Shapiro et al. 2017) as mixed farms rely on animal power (80% of crop production still relies on animal traction, Azage 2010) and practice smallholder dairy production. The highland areas also have traditions of beef production through fattening, mainly focused on oxen retired from field work (FAO 2018). Despite the higher numbers of livestock in mixed systems, 95% of animal export trade comes from pastoral and agropastoral production in the low drylands and this trade is calculated as providing 16–19% of foreign trade earnings for the country (Shapiro et al. 2017a).

A recent detailed livestock sector analysis designated four systems (lowland grazing-LG, mixed rainfall deficient -MRD, mixed rainfall sufficient -MRS and specialized production-SP) and then further parsed these livestock systems into 40 subsystems (see Figures 11a and 11b) (from Shapiro et al. 2017). In this context the specialized systems are dairy systems, cattle fattening and poultry systems and a minuscule apicultural sector. Specialized dairy production systems are limited to the mixed rainfall sufficient zones (see Figure 11c) and provide only a minuscule portion of the overall dairy production. Recent reviews calculate that 98% of the dairy production still comes from smallholder systems (FAO and NZ 2017).

Other studies have found similar results stating that 97% of the countries milk production comes from traditional production systems relying on indigenous breeds (Feleke 2003). Poultry production also relies mainly on indigenous breeds maintained in informal or “backyard” conditions (Shapiro et al. 2017a).

Figure 11a and 11b: Livestock production systems a, and subsystems b. (Shapiro et al. 2017)



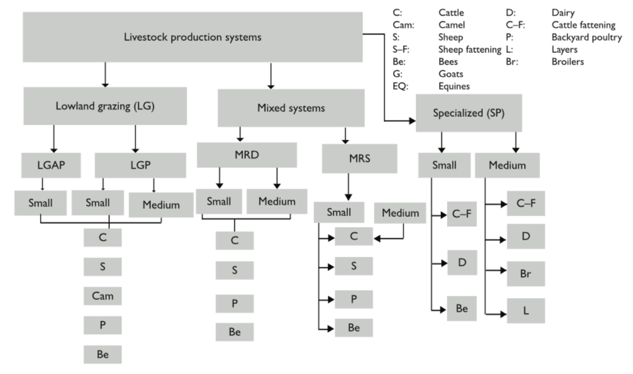
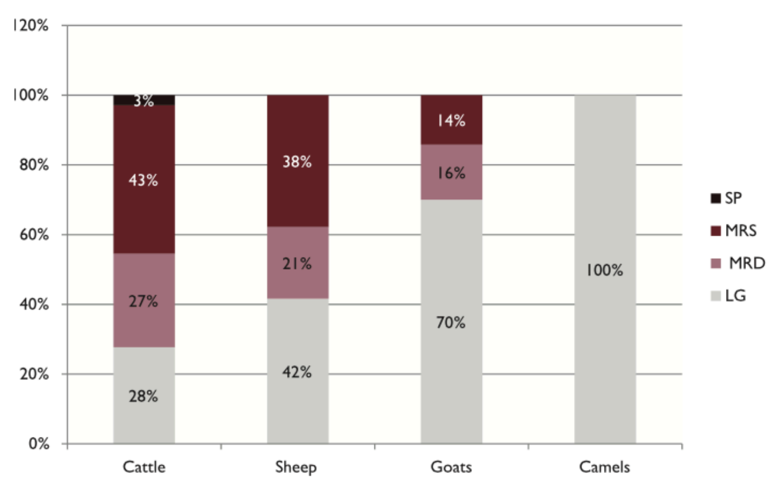


Figure 11c: Percentage distribution of livestock by the four-production zones. LG - Lowland Grazing, MRD - Mixed Rainfall Deficient, MRS - Mixed Rainfall Sufficient, and SP - Specialized Production. Graphic from Shapiro et al. (2017). Data credited to Central Statics Agency and expert opinion.



The Ethiopian Central Statics Agency (2016) calculated the national livestock herd as 57.83 million cattle, 28.89 million sheep, 29.70 million goats, 2.08 million horses,7.88 million donkeys, 60.51 million poultry, 5.92 million beehive, 0.41 million mules and about 1.23 million camels. Revisions to this 2016 data were done based on more specific sector counts and expert inputs; this 2017 LSA increased the estimated camel numbers by four-fold (55.2 million cattle, 29 million sheep, 29 million goats, 4.5 million camels, 50 million poultry, from Shapiro et al. 2017).

A review of the livestock sector for Ethiopia (Azage et al. 2010) suggested that the sector has much potential for expansion in the productive capacities (both meat and milk) and in expanding the reproductive performance of animals. The 2017 review (Shapiro et al. 2017) concluded that fodder deficit, animal health and genetics are the main constraints to productivity and suggests that policy and investment should target improving veterinary coverage, promoting fodder production and facilitating genetic improvements (Shapiro et al. 2017). This same review found that goats and chickens provided the highest direct economic benefit to impoverished households and noted that if poverty reduction is to be a priority, these livestock should be the focus of development.

Key resources

Amede, T., Auricht, C., Boffa, J.M., Dixon, J., Mallawaarachchi, T. et al. 2017. *A farming system framework for investment planning and priority setting in Ethiopia*. ACIAR Technical Reports Series No. 90. Canberra, Australia: Australian Centre for International Agricultural Research.

FAO (Food and Agriculture Organization oft he United Nations). 2018. *Africa sustainable livestock 2050: livestock production systems spotlight Ethiopia cattle sectors*. I8271EN/1/01.18

ICPALD (IGAD Center for Pastoral Areas & Livestock Development). 2013. *The contribution of livestock to the Ethiopian economy*. Policy Brief 5/CLE/8/2013. ICPALD.

Shapiro, B.I., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset G. and Mechale. H. 2017. *Ethiopia livestock sector analysis*. ILRI Project Report. Nairobi, Kenya: International Livestock Research Institute (ILRI). https://hdl.handle.net/10568/92057

Food and nutrition security

Ethiopia is a food insecure country. The World Bank classifies it as a low income, high commodity import and low commodity export dependent economy. Overall caloric input of households is dependent on cereals and dietary diversity is limited throughout the population (FAO 2010). Though milk is a major nutrient source, per capita consumption for Ethiopia is much lower than in the regional neighbours Sudan and Kenya (FAO and NZ 2017). The most recent statistics on nutritional indices indicate that though the percentage of children under five with stunting and acute malnutrition has decreased in the last decade, total numbers still remain high. PoU for the entire population is at 20% and for children under five, prevalence of wasting is at 10% and prevalence of stunting is at 38% (FAO et al. 2019).

Children in rural areas are more likely to be malnourished than those in urban areas, though variation exists region to region. Ethiopia has one of the largest national populations in Africa, and unfortunately often ranks in the highest tiers for population numbers with hunger or malnutrition (Mohamed 2017). Many studies have been reported on food and nutrition security in Ethiopia, often highlighting the role of drought in food insecurity for the country and noting the increased likelihood of food insecurity under raising climate variability with climate change. (Adem et al. 2018; Amare and Simane 2017; Birara et al. 2015; Jemal and Kung 2014; Ramakrishna and Asefa 2002; Kaluski et al. 2001).

Key resources

Mohamed, A.A. 2017. Food security situation in Ethiopia: A review study. *International Journal of Health Economics and Policy* 2(3): 86–96. doi: 10.11648/j.hep.20170203.11

Climate change

Ethiopian climate conditions vary across the large country as an outcome of elevation differences and the fluctuations of the ITCZ. The main rainy season for the majority of the country is July through September, with some north and central regions having a small second season of light rains from February to May. However, the more southern regions have a more distinct bimodal rainfall pattern, with March to May as the first and heavier rains, and October to December as the second rainy period. Climate change models for Ethiopia follow the general trend for all of the GHA; the models have general uniformity in increased temperatures but have less consistency, or certainty, in precipitation change patterns (McSweeney et al. 2010). Overall climate models show warming with projections of 1.1 to 3.1°C by the 2060s, and projections of 1.5 to 5.1°C by the 2090s (McSweeney et al. 2010). Global climate models have predicted increases in rainfall, but this is largely associated with increases in extreme events in the highlands (Niang et al. 2014), particularly with increases in the October to December short rains (McSweeney et al. 2010).

However, and even though Ethiopia has already experienced increases in mean annual temperatures of 1.3°C from 1960 to 2006 (McSweeney et al. 2010), studies of rainfall data show an overall rainfall decrease of 10% from 1948 to 2006 (Jury and Funk 2013). An evaluation of 30 years of precipitation data (1984–2014) of six meteorological stations in the north highlands found seasonable variability in rainfall change, with slight (insignificant) decreases in the spring season (March–May) for all stations, and significant increases during the summer (July to September) for three of the six stations. Still, these increases over the summer months had no perceptible pattern in frequency or duration of extreme events (Yimer et al. 2018). Another recent meteorological review found trends of minimal decreased precipitation across Ethiopia in the July through September rains and significant variability in rains for February through May (Asaminew and Zhang 2019). Other models have found decreased potential growing season (12–35% shortened) (Kassie et al. 2014).

All of these studies point toward profound challenges for rainfed agriculture with subsequent negative effects for food security (FDRE 2011). Similarly, pastoral and agropastoral production is reduced under droughts as rangelands degrade and livestock come under weather related stress and increased vulnerability to pests and diseases (Kassaye 2010). Despite these livestock vulnerabilities a review of food security under climate change for the mixed crop-livestock region of the upper Blue Nile region of Ethiopia found that livestock and landholdings were the key factor for differences between food insecure and food secure households (Amare and Simane 2017). Under this analysis, support of the livestock sector in smallholder systems is important for improved food security.

Key resources

McSweeney, C., New, M. and Lizcano, G. 2010. *UNDP climate change country profiles: Ethiopia*.

Mahoo, H., Radeny, M., Kinyanji, J. and Cramer, L. (eds). 2013. *Climate change variability and risk assessment of agriculture and food security in Ethiopia: Which way forward?* CCAFS Working Paper No 59. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security.

GHG emissions and livestock

Ethiopia's emissions for 2011 were calculated at 141 million $MtCO_2$ equivalent, with 61% of that emission coming from the agriculture sector. Enteric fermentation (52%) and manure left on pastures (37%) were the biggest factors in that agricultural contribution (USAID 2015). A further study of the dairy sector in Ethiopia calculated the dairy sector emitted 116.3 million tons of CO_2e in 2013, of which enteric fermentation accounted for 87% of this dairy sector emission. This emission was mainly from rural mixed crop-livestock (56%), and pastoral and agropastoral (43%) dairy production. Commercial dairy operations produce only a small percent of the emission (1.3%) as this sector is not large for the country (FAO and NZAGRC 2017). In June 2017 Ethiopia filed its first INDC pledging a limit of 145 $MtCO_2e$ or lower for year 2030 (FDRE 2017).

Key resources

FAO and NZAGGRC (New Zealand Agricultural Greenhouse Gas Research Centre). 2017. *Supporting low emissions development in the Ethiopian dairy cattle sector – reducing enteric methane for food security and livelihoods*. Rome, Italy.

FDRE (Federal Democratic Republic of Ethiopia). 2017. *Intended nationally determined contribution (INDC) of The Federal Democratic Republic of Ethiopia*. Submission date March 3, 2017.

Climate-smart livestock

In 2011 the Ethiopian government reformatted its entire national planning around an initiative called the Climate Resilient Green Economy (CRGE). A comprehensive strategy was developed for orienting all sectors of society towards development that is both sustainable and low in greenhouse gas emissions. The four pillars of the plan are to:

> 1. Improve crop and livestock production practices for higher food security and farmer income while reducing emissions;
> 2. Protect and re-establish forests for their economic and ecosystem services, including as carbon stocks;
> 3. Expand electricity generation from renewable sources of energy for domestic and regional markets; and
> 4. Leapfrog to modern and energy-efficient technologies in transport, industrial sectors, and buildings.
>
> –Federal Democratic Republic of Ethiopia (2011)

For Pillar 1 a priority is that the productivity of farms and animals must be increased rather than increasing the land area cultivated or cattle headcount. For the livestock sector the CRGE further sets out the priorities of rangeland management, mechanizing draft power with 50% removal of animal draft power, support for lower emission protein consumption (i.e. poultry) and 'increase animal value chain efficiency to improve productivity, i.e., output per head of cattle via higher production per animal and an increased offtake rate, led by better health and marketing.' The CRGE framework fundamentally included climate resilience in the strategy, though the details for resilience planning were not in the 2011 report. These climate resilience details are now available with the release of the National Adaptation Plan (NAP) (FDRE 2019). Through the adaptation planning process, 18 multi-sectoral adaptation options were identified (Table 6).

Table 6: The eighteen multi-sectoral adaptation options identified for National adaptation programmatic initiatives in keeping with developing the Climate Resilient Green Economy (FDRE 2019).

1	Enhancing food security by improving agricultural productivity in a climate-smart manner
2	Improving access to potable water
3	Strengthening sustainable natural resource management through safeguarding landscapes and watersheds
4	Improving soil and water harvesting and water retention mechanisms
5	Improving human health systems through the implementation of changes based on an integrated health and environmental surveillance protocol
6	Improving ecosystem resilience through conserving biodiversity.
7	Enhancing sustainable forest management.
8	Building social protection and livelihood options of vulnerable people
9	Enhancing alternative and renewable power generation and management
10	Increasing resilience of urban systems
11	Building sustainable transport systems
12	Developing adaptive industry systems
13	Mainstreaming endogenous adaptation practices
14	Developing efficient value chain and marketing systems
15	Strengthening drought, livestock and crop mechanisms
16	Improving early warning systems
17	Developing and using adaptation technologies
18	Reinforcing adaptation research and development

The NAP notes that achieving these priority options will require cross-sectoral and transregional coordination, which creates its own priority for governmental institution development. Brief overviews of the goals and intent for each priority is provided in the NAP.[15] Analyzing these for their inclusion of the livestock sector brings to light potential opportunities for climate-smart livestock approaches in Ethiopia. In the 18 priorities, only three explicitly mention livestock and livestock initiatives; These are priorities 1, 14 and 15. Priority 1 covers many practices, of which some are known CSA approaches. Listed Priority 1 livestock strategies are: improved breeding, feeding, pasture, and grazing management; enhanced veterinary services; enhanced water availabilities and conservation; and appropriate

[15] See Pages 55-61 of the FDRE 2019 for these descriptions.

technology adoption. Under this Priority, policy support for livestock sector transformations will be likely. Intensification of practices, especially for dairy production, have potential for GHG mitigation and livelihood productivity support. Under these transformational shifts, consideration should be given to possibilities of encouragements of livestock switching (from cattle to camels) in particular environments, or for expansion of chicken production systems (see discussion of priority 10 below). Priority 14 addresses support for value chain resilience for livestock, which includes production of value addition livestock products and supporting the marketing of said products. Priority 15 address the need to support financial mechanisms such as drought, livestock and crop insurance tools that aid the resilience of livestock systems.

Four priorities relate implicitly to livestock production systems but do not explicitly address livestock in the descriptions; These are Priorities 3, 4, 7, and 8 respectively. In discussing these priorities, opportunities for climate-smart livestock approaches will be introduced. Priority 3 is for natural resource and landscape sustainability and includes "rehabilitation of degraded lands". A major portion of the landscape of Ethiopia that is experiencing climate change and land use associated degradation is the dry lowlands associated with extensive pastoralism. Rehabilitation is an opportunity for deployment of climate-smart livestock practices that aid in supporting extensive pastoralism where it is the most viable livelihood option while also mitigating against the high GHG rates associated with pastoralism. Climate-smart approaches that mitigate the GHG emissions can be pursued though targeted intensification of management practices (i.e supplemental feeding, breeding support, veterinary care) while also supporting the transhumant movement that makes pastoralism viable in high variability landscapes. Support for land rehabilitation can also draw on priority 13, traditional ecological knowledge, and integrate into land planning traditional pastoral management practices and knowledge of landscape level variability and microclimates.

Priority 4 is for improving soil water retention as part of interest in increasing irrigated agricultural practices. These goals can be linked to livestock climate-smart initiatives in manure management, with manure collection and mulching used as soil amendments (though care is needed for proper techniques to limit N_2O release). Priority 7 is for sustainable forest management. Silvapastoralism is a well researched climate-smart livestock strategy and synergies should be sought between these forest management initiatives and livestock systems. Priority 8 is for social protection and livelihood options for vulnerable people, mentioning women, children and impoverished communities. Practices include improving access to credit, promoting livelihood diversification and arranging voluntary resettlement/migration. This priority is livestock adjacent as it is likely that some of the targeted "impoverished communities" to be addressed in this priority are pastoral communities. Site or community specific CSA evaluations on productivity (livelihood viability), adaptation and mitigation potentials must be done so that programmatic pushes for livelihood diversification (pastoral to agropastoral), or resettlement (nomadic to peri-urban) are not done from biased assumptions that pastoral practices are not resilient or climate smart.[16]

[16] This claim has been seen in some writings that focus on the GHG emissions aspect of pastoral production. Though "livestock production system transformations" have been modeled (Havlík et al. 2014) to have high mitigation potential, such transformations are not necessarily the Climate Smart option in certain locations. In some landscapes pastoralism is the most adaptive production system (FAO and IFAD 2016).

Two other priorities are potential spaces for development and deployment of livestock systems that could aid in the green economy development. Priority 9 discusses institutional interest in alternative energy sources. Biogas production from manure, both at small and larger scales has a growing proof of concept in research and case study applications. Synergistic project development between livestock systems for productivity gains and the energy sector for alternative energy initiatives are clear climate-smart livestock opportunities. Similarly, Priority 10 addresses the resilience of urban systems, and lists green space protection and household and urban waste management. As above, biogas is a CS opportunity for urban waste streams. Synergies should also be sought to link potential green waste streams towards livestock production. Urban agriculture, and small livestock systems could also be promoted, especially in the peri-urban areas. Promotion of poultry is part of the CRGE, but other urban based "livestock" could include rabbits (for meat), vermiculture (for waste management and production of a marketable soil amendment) and urban bee keeping (for livelihood diversification and biodiversity support).

Priority 17 and 18 highlight the interest and institutional backing that exists in Ethiopia for trying new and alternative technologies and for investing in research for knowledge development. Ethiopia is already the site of many CSA initiatives (Njeru et al. 2016 and CIAT, BFS/USAID. 2017 for detailed reviews of CSA in Ethiopia; see Kipkoech et al. 2015 and Ogada et al. 2018 for regional case study reports that include projects done in Ethiopia). In brief, climate-smart adoption in Ethiopia is predominantly in the crop and water management sector; livestock climate-smart work is mainly in forage and fodder initiatives and biogas. The CIAT, BFS/USAID review identified three high potential climate-smart livestock activities for Ethiopia: feed and feeding systems improvement; veterinary services improvement; and conservation and development of improved cattle breeds. They report a low (<30% uptake) of feed and feeding systems improvements, and a medium (30–60%) uptake of veterinary services improvement and did not report on breeding.

Overall, the potential for climate-smart livestock approaches in Ethiopia is large. Research is showing that dairy intensification and poultry production will be important tools in meeting productivity and mitigation goals (YONAD 2015). Care is needed though in not allowing the goals of intensification and higher off take rates to dominate decision making for management of rangelands and pastoral systems. Beyond this interest in intensification, the governmental interest in pursuing a green economy generates an enabling environment for experimentation and adoption of new technologies and agricultural practices. Individuals interested in climate-smart livestock should be leveraging the cross-sector potentials of the 18 NAP priority points to investigate other ways in which livestock (large and small) can be used in novel Climate Smart livelihood developments in Ethiopia.

Key resources

CIAT and BFS/USAID. 2017. *Climate-smart agriculture in Ethiopia*. CSA Country Profiles for Africa Series. Washington, D.C.: International Center for Tropical Agriculture (CIAT) and Bureau for Food Security, United States Agency for International Development (BFS/USAID). (Available from https://ccafs.cgiar.org/publications/climate-smart-agriculture-ethiopia#.Xbc2niVS_OQ) (Accessed 29 January 2020)

FAO. 2016a. *Ethiopia climate-smart agriculture scoping study*. Addis Ababa, Ethiopia: FAO.

Kenya

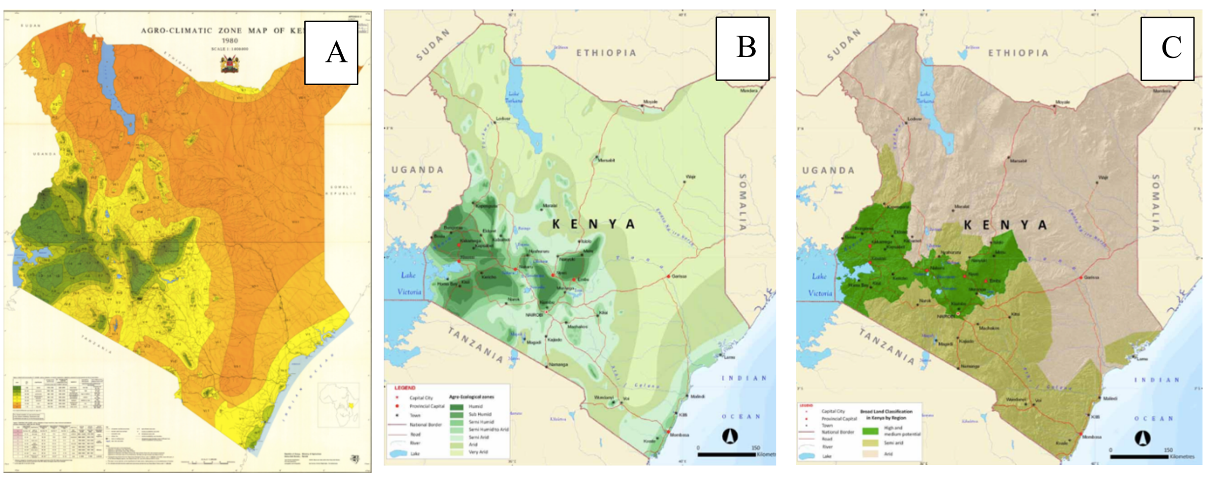
Agricultural production and agroecological zones

Early work on mapping of soils and rainfall lead to development of the zone map for Kenya with seven zones, originally considered agro-climatic zones (see Figure 12a) but now used as agroecological zones (see Figure 12b). More generally the land is grouped into three divisions of low, medium or high potential for agricultural production (see Figure 12c). Only 20% of the land is classified as having medium or high agricultural potential; the other 80% is arid and semi-arid land, commonly referenced as the Kenyan ASAL.

Figure 12a: Agro-climatic zone map for Kenya from 1980, by the Ministry of Agriculture Kenya Soil Survey. https://esdac.jrc.ec.europa.eu/images/Eudasm/Africa/images/maps/download/afr_keacz2.jpg

Figure 12b: Agroecological zones map from the 2010 State of the Environment report (NEMA 2011a).

Figure 12c: The landscape of Kenya classified by potential for agriculture. Medium and high potential are marked in bright green. 80% of the land is arid (tan) or semi-arid (pale green). (NEMA 2011a)



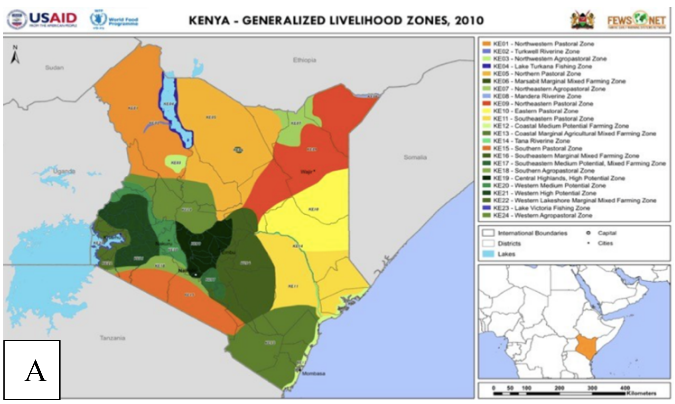
This division between ASAL and the more humid highlands is heightened by the subsequent differences in livelihood diversity (see Figures 13a and b). The ASALs are dominated by pastoral and agropastoral production with some mixed crop-livestock in riverine or water rich areas. Reports agree that the ASALs have historically housed the majority of the livestock (listed as 70% of livestock in GoK 2008, 50% of livestock in NEMA 2011a, 60% of national herd in RoK 2019) but only a small portion of the population (¼ of the total population, NEMA 2011a). In contrast smallholder mixed crop-livestock systems are dominant in the highlands, but the types of crops and scale of farms vary by region. Nationally, smallholders (0.2–3 hectares) account for 98% of land ownership and produce up to 75% of the agricultural production (NEMA 2011a), but only hold 56% of agricultural land. Only two percent of land holders have medium or large farms, but these account for 54% of the agricultural production land (Mati 2016). Large farms largely produce tea, coffee, wheat, and maize, though some large landholdings are for beef and dairy production. In 2019 it was calculated that there are 250 large holdings that are categorized as ranches which are held as public, private, group, company or cooperative entities (RoK 2019).

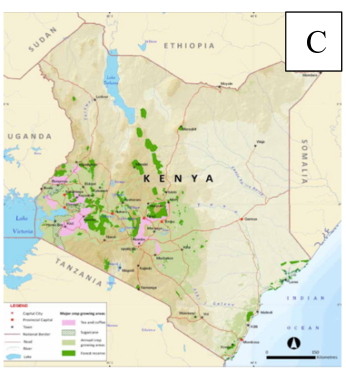
Rain fed production is the most common agricultural system, especially amongst smallholders. Irrigation is used in only 2.4% of agricultural cultivation area, but accounts for 18% of the agricultural GDP (FAO 2015). Crop production includes a substantial export oriented production of tea, coffee and horticultural crops (cut flower and vegetables). The ASALs do not receive sufficient rainfall for successful rainfed production, however it is still attempted in areas and incorporation of irrigation is proposed as a development scenario for appropriate semi-arid lands (NEMA 2011a).

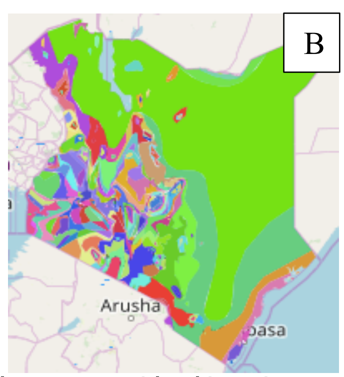
Figure 13a: Generalized 2010 livelihood zone map from FEWSNET. From http://fews.net/east-africa/kenya/livelihood-zone-map/march-2011

Figure 13b: Detailed agro-climatic zones map for Kenya, from GeoPortal GIS dataset on line at http://geoportal.icpac.net/layers/geonode%3Aken_aczones

Figure 13c: Kenya agricultural production zones by commodity crops, annual crops and forest reserves (from NEMA 2011a)





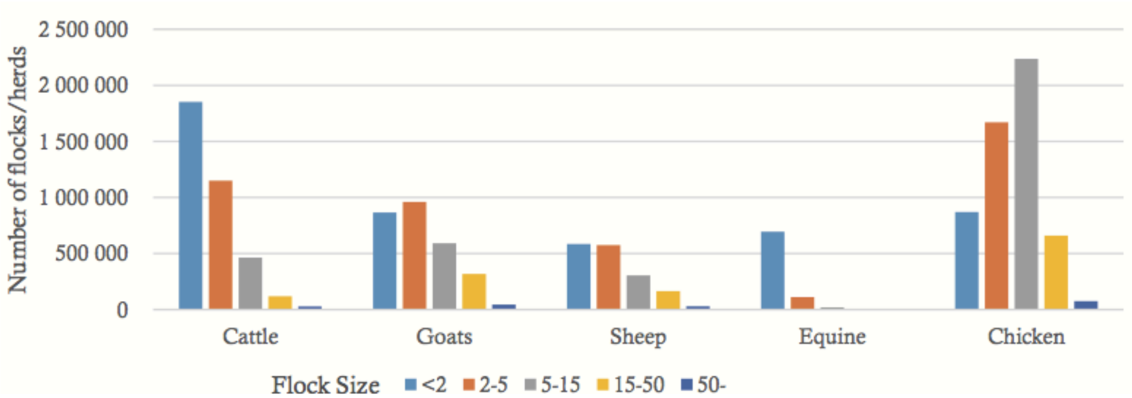


Agricultural production is an important employment and livelihood sector for the entirety of the country. As much as 57% of national employment is in the agricultural sector, which contributes 34% of the national GDP[17]. Within the different agroecological zones the relative importance of agricultural and livestock varies. The ASALs are characterized as having high levels of poverty and absolute poverty (Mati

[17] https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS. Data from 2018.

2016) and in these areas up to 90% of employment comes from the livestock sector (RoK 2019). The ASAL livestock production is dominated by subsistence and local trade production and is under integrated into the national market economy (RoK 2019).

Figure 14: Herd and Flock size for Kenya in 2015. Image from FAO (2017).



Throughout Kenya the livestock sector is dominated by smallholders (Figure 14) but still the livestock sector contributes 12% of the national GDP and 42% of the agricultural GDP (RoK 2019). The dairy sector alone is calculated as providing 14% of the agricultural GDP (FAO and NZAGGRC 2017) However, the official Kenya Bureau of Statics calculations could be underestimating the full value of the livestock sector to the Kenyan economy. Behnke and Muthami (2011) point out that KBNS takes a market and commodity chain approach to their livestock analysis. In contrast their re-analysis of the livestock sector based on the same 2009 data found a 170% difference in value calculation; the KBNS valued the livestock sector at 127.723 billion Ksh whereas Behnke and Muthami found the sector to be 345.448 billion. Most importantly, in this reanalysis, the authors found that though the meat production values were similar between their calculation and the KBNS numbers, the milk sector KBNS value was 1/20th of their calculated value.

This is especially salient when the milk sector is known to be dominated by smallholders. Over a quarter of total households in Kenya can be classified as smallholders engaged in milk production; in rural households this percentage goes up to 35% (FAO and NZAGGRC 2017). Smallholder production per animal is found to be half that of cattle on medium and large-scale dairy production farms (with 20–100 cattle) but despite this, smallholders are calculated to be producing 75% of the cattle milk sector (Makini et al. 2019). A systematic review of Kenyan livestock production literature found a similar lower production rate for smallholder systems (Onono et al. 2012). Following on from Behnke and Muthami's findings it is likely that non-market value of milk has been historically underestimated, so even at lower production rates, smallholder production is very important for food and nutrition security. Similarly, Makini et al.'s (2019) review of the dairy sector (cattle, goat, and camel) also found that smallholder goat milk is largely (57%) for household consumption and that camel milk is an important nutrient source in the northern pastoral communities despite the relatively low levels of production per camel (when compared to potential breed based production) (Makini et al. 2019). The value of the livestock sector in Kenya to livelihoods and nutritional status is also underestimated through the lack of calculation of the direct value of animal traction in the service and industrial sector as well as in agriculture sector (Behnke and Muthami 2011). For a full overview of the recalculated livestock value in the Kenyan economy see the ICPALD policy brief.

Key resources

FAO (Food and Agriculture Organization of the United Nations). 2017. *Africa sustainable livestock 2050: Country brief kenya*. I7348EN/1/06.17.

ICPALD (IGAD Center for Pastoral Areas & Livestock Development). 2013. *The contribution of livestock to the Kenyan economy*. Policy Brief 4/CLE/8/2013.

Makini, F.W., Mose, L.O., Kamawu, G.K., Mulinge, W.W., Salasya, B. et al. 2019. *Innovation opportunities in dairy livestock in Kenya*. Guidebook. Forum for Agricultural Research in Africa.

Food and nutrition security

Kenya is a moderately food insecure nation, but this insecurity is not uniform across the nation. Kenya has been characterized as having high wealth disparities, and food insecurity is highest in the urban poor and the rural poor of the ASAL. For the 2016–2018 period food insecurity in Kenya was measured as 19.1% of the total population (FAO et al. 2019). The FAO measure of PoU showed improvement in the decade between 2002 (33.2% PoU) and 2013 (22.3% PoU) but since then PoU has increased steadily (2016–2018, 29.4% PoU) (FAO et al. 2019).

Drought conditions increase food insecurity in the ASALs (Huho and Mugalavai 2010). These droughts and a major pest outbreak (Fall Army Worm) also devastated maize production in the highland growing areas causing shortages throughout Kenya in 2016 and 2017. Kenya is classified as a lower-middle income, high commodity export and low community import dependent economy (FAO et al. 2019). However, dietary diversity in Kenya is very low, with high dependence on maize. Maize production accounts for almost four-fifths of all grain output; 70% of this maize production is done by smallholders who retain up to 60% of the harvest. But even at this production and retention level, 58% of smallholders buy more maize than they produce (D'Alessandro et al. 2015). Commodity imports are used to make up cereal crop short falls (especially maize) that occur in poor growing seasons and as such food security becomes linked to international commodity markets. Crop shortfalls in the recent drought years were offset by governmental policies for higher import allowances coupled with price caps to avoid commodity costs becoming unbearably high for rural and urban poor.

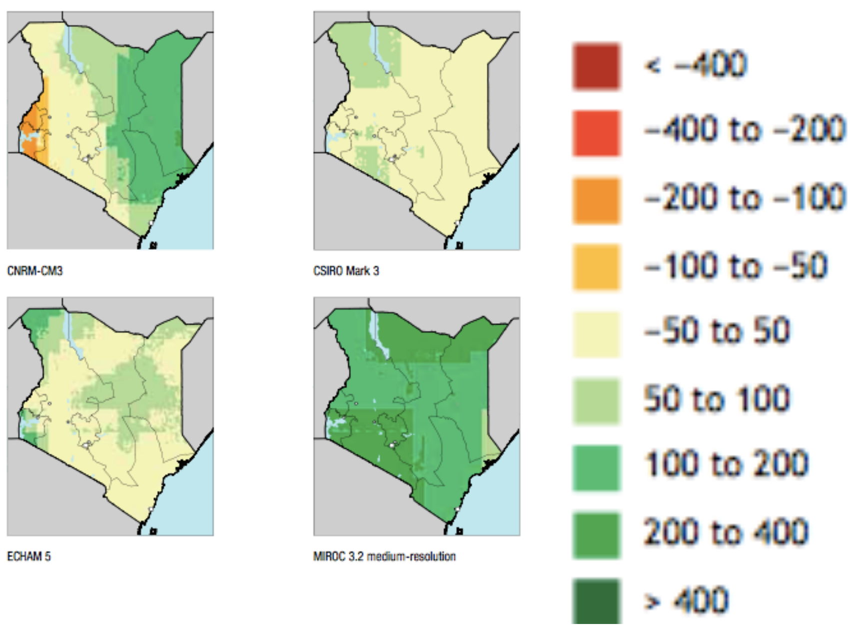
Climate change

Kenyan climate has a strong bimodal seasonality with rainfall patterns influenced by the ITCZ and ENSO events. Western Kenya and the highlands also have air and precipitation patterns influenced by the inland 'sea' Lake Victoria. A recent analysis of temperature and precipitation trends from historical data found a general increase in temperature but lack of clear trends in rainfall change (Skogsied 2017). Two Kenya climate and climate model review reports agree that temperature trends are upward, with increased temperatures for both high temperatures and low temperature days (Gosling et al. 2011; McSweeney et al. 2010). A regional synthesis placed the temperature increases for Kenya between 0.8 to 1.5°C for the 2030s and 1.6 to 2.8°C for the 2060s (MoFAN 2018a).

Precipitation trends in recent years are harder to quantify as rainfall data for Kenya is limited with only a few collection sites per sub region (Gosling et al. 2011). From the data accessible for 1960–2003 there is 'limited evidence for decreasing precipitation' (Gosling et al. 2011). However, the other trend found in the precipitation data is that 'there is an increasing, but no statistically significant trend in the proportion of rainfall occurring in heavy events' (McSweeney et al. 2010).

This lack of clear trends in historical rainfall mirrors the lack of certainty in models of future precipitation. A review of four main climate models on Kenya found that precipitation increases are not uniform over the country across the models (see Figure 15). The CNRM-CR3 model shows an east west gradient with the west losing rainfall and the east becoming wetter. The CSIRO Mark 3 and ECHAM 5 models both lack clarity in the trends as most of the country is marked as either losing or gaining precipitation (-50 to 50). In contrast to these three models, the MIROC finds precipitation increases across the whole country.

Figure 15: Precipitation changes in Kenya under four different models. Colours represent mean annual precipitation in millimetres as projected for years 2000–2050 under A1B scenario. Images copied from Odera et al. 2013, they credit the data to Jones, Thornton, and Heinke 2009.



With variability in the rainfall predictions, outcomes of climate change on food production are equally unclear. Models in fact point to potential increases in arable land, especially for maize, however overall production yields are not likely as overall yield loss from heat stress is expected to increase (see Odera et al. 2013 and Gosling et al. 2011 for reviews of cropping systems and yield under climate change). An analysis of livestock revenue loss under potential climate change in Kenya concluded that the potential of a 1% increase in temperature 'would decrease the livestock net farm revenue by about 38.2% and that the temperature increases would have the highest impact in the already low production potential areas of the ASALs' (Lagat and Nyangena 2016).

Key resources

Gosling, S.N., Dunn, R., Carrol, F., Christidis, N., Fullwood, J. et al. 2011. *Climate: observations, projections and impacts: Kenya*. Nottingham, UK: UK Met Office.

McSweeney, C., New, M and Lizcano, G. 2010. *UNDP climate change country profiles: Kenya*.

Odera, M.M., Thomas, T.S., Withaka, M. and Kyotalimye, M. 2013. Kenya. In: Waithaka, M., Nelson, G.C., Timothy S. and Kyotalimye, M. (eds), *East African agriculture and climate change, a comprehensive analysis*. Washington, D.C.: International Food Policy Research Institute (IFPRI): 183–212. (Available from http://www.ifpri.org/publication/kenya-0) (Accessed 29 January 2020)

GHG emissions and livestock

In the 2015 INDC report for Kenya, GHG emissions were reported as 73 Mt CO_2e, which were calculated from 2010 data (RoK 2015). Other reviews of Kenya's GHG bring the estimate down to 60.2 Mt CO_2e (USAID 2017, using WRI CAIT 2.0 2017 data). This WRI CAIT number does not include estimates from land use change and forestry; there is currently debate whether this LULUCF is a sink or a source of CO_2 in Kenya as the rate and extent of deforestation is uncertain (USAID 2017). However, what is clear from all emissions reports is that the Agricultural subsector releases the majority of national emissions (62.8% from Agriculture in USAID 2017; 78% from Agriculture (41%) and LULUCF (37%) in RoK 2015), with livestock being the biggest contributor (livestock is 90% of the agricultural emission in FAO and NZAGGRC 2017; and is 96.2% of the agricultural emissions in World Bank and CIAT 2015). The two forms of livestock-based emissions, enteric fermentation (55%) and manure left on pasture (36.9%) make up the bulk of all agriculture emissions (USAID 2017).

Key resources

RoK (Republic of Kenya). 2015. *Kenya's intended nationally determined contribution*. 23 July 2015. Nairobi, Kenya: Ministry of Environment and Natural Resources.

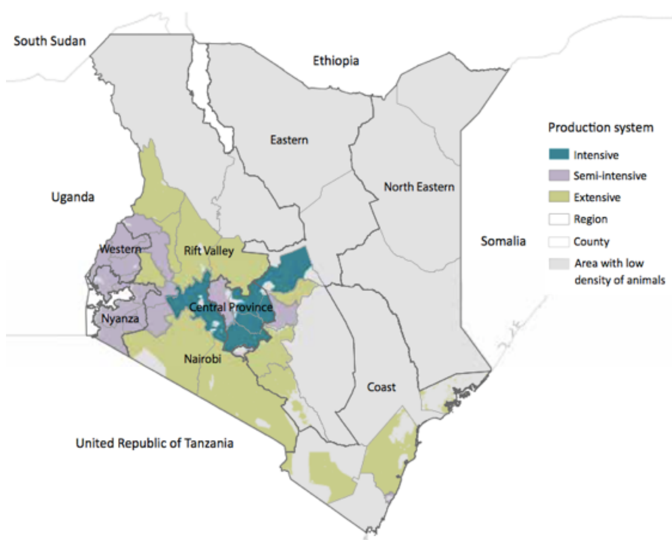
USAID. 2017. *Greenhouse gas emissions in Kenya*. Nairobi, Kenya: WRI, CAIT and USAID.

Climate-smart livestock

The review by Odera et al. (2013) of climate change impacts for Kenya agricultural has minimal reference to livestock systems and no mention of livestock in their brief end recommendations. The 2015 World Bank and CIAT CSA review for Kenya highlights that livestock CSA adoptions have been low, but a number (biogas production, improved pasture management, grass-legume fodder systems in both intensive dairy and semi-extensive dairy) have high potential as CSA practices in Kenya. Biogas production and grass-legume fodder in intensive dairy have had some adoption and in the financial sector Kenya has been a world leader in the development and adoption of crop and livestock index-based insurance frameworks. (World Bank and CIAT 2015). Kenya has also been the site of many case study applications of CSA practices some of which encompass livestock systems: see Kipkoech et al. (2015) on fodder production, rotational grazing, improved breeding, and stocking, feed and manure management; FAO 2016 on biogas, dairy herd management, livelihood diversification including livestock options, soil fertility and manure management; Ogada et al. 2018 on improved breeds adoption and veterinary service provision.

Because of general knowledge of the GHG emissions and climate change challenges associated with dairy production and with extensive systems (see Topic Review) there is much institutional interest in intensification practices for their adaptation and mitigation potential in the Kenyan livestock system. The dairy sector is the largest agricultural subsector in Kenya and was reviewed for its emissions and mitigation potential (FAO and NZAGGRC 2017). This review found that 88% of the dairy sector emissions come from enteric fermentation. There are important differences in absolute amounts versus intensity differences (emissions per unit milk production) between the extensive, semi-intensive and intensive systems. For GHG emissions from the dairy cattle sector, semi-intensive production currently produces the most emissions (48% of the dairy sector total), then extensive (32%) and finally intensive (21%). However, the emission intensity per standardized unit of quality milk (fat and protein corrected milk) is low for intensive (2.1 kg CO_2e/kg FPCM), double that for semi-intensive (4.1 kg CO_2e/kg FPCM) and more than triple that for extensive (7.1 kg CO_2e/kg FPCM). Mitigation strategies for the dairy sector fall into the three main categories of changes in diet, changes in health, and changes in genetic potential (see FAO and NZAGGRC 2017 for methods and mitigation potentials).

Figure 16: Map showing the distribution of the various dairy production systems. Note the exclusion of the ASALs from inclusion in the 'extensive' production system. Map from FAO and NZAGGRC (2017)



However, this review is limited in its scope as it did not include the majority of the ASAL lands in its review of extensive production (Figure 16). This is important to note as the review evaluates mitigation strategies for each of these production systems. Changing management and feeding practices is identified as a feasible mitigation strategy for the extensive systems in the higher production zones. These changes may not be feasible adaptation and mitigation strategies for the extensive systems in the ASALs where fodder production is limited, and transportation distances are high. However, these extensive ASAL systems are identified as prime zones for mitigation interventions: 'investments in improved pastoral livestock keeping practices are essential for achieving reductions in methane emissions from agriculture. Introducing improving breed and feeding regimes, the use of biodigesters for biogas production have the potential to reduce greenhouse gas (GHG) emissions, particularly in key areas such as the arid and semi-arid lands (ASALs)' (World Bank and CIAT 2015). Attention should be given to developing these climate-smart livestock projects that address the context specific productivity and adaptation challenges of the ASALs in light of this interest in ASAL emission mitigation.

Kenya is tackling these complexities in livestock sector management through the national adoption of a CSA framework for their climate change adaptation and mitigation needs. In the NDC for the country (RoK 2015) the listed agriculture sector adaptation plan is 'enhance resilience of agriculture, livestock, and fisheries value chains by promoting CSA and livestock development' and for mitigation strategies "CSA in line with the National CSA Framework". In 2018 Kenya published a comprehensive climate smart framework for its agricultural sector planning and includes many livestock directed actions (RoK 2018).

The framework identifies four thematic components for government action: 1. Institutional coordination; 2. Agricultural productivity and integration of value chain approach; 3. Building resilience and appropriate mitigation actions; and 4. Communication systems on CSA extension and agro-weather issues. Under section 2, it lists a number of adaptation technologies to be pursued: Seven of which are for crop systems, three for fish, and ten for livestock (Table 7). A further seven relate to all agricultural systems (crop, livestock and fisheries), and four relate to general promotion of CSA and awareness raising.

Table 7: The ten adaptation strategies proposed for livestock systems in the National CSA planning document (RoK 2018).

Promote rehabilitation of degraded rangelands
Introduce improved exotic livestock breeds and improved indigenous/local adapted breeds
Promote adoption of low emission technologies from the livestock value chain.
Improved nutrition through supplementation, forage and fodder conservation and irrigated pastures and fodder
Adequate disease surveillance and disease control and regular vaccination campaigns
Increase community managed drug stores through provision of livestock drugs within reach of pastoralists
Promote livestock value chain diversification
Intensify surveillance and control of emerging livestock pests and diseases
Promote sustainable livestock stocking capacity
Harmonize livestock vaccinations across the bordering counties and across the international borders

Under section 3 the framework addresses adaptation and mitigation strategies to build resilience, providing extensive action points for various economic sectors. Livestock related strategies that address soil and land degradation include land management for rangeland rehabilitation and improved grazing practices. Rangeland management is also a listed component of protecting water and natural resources. Adaptation and resilience in the livestock sector are also to be pursued by further development and implementation of index-based livestock insurance and the development of supportive agronomic and meteorological information and communication networks. The framework then specifically addresses the need to have projects that have synergistic relationships between improving resilience and productivity while also addressing the GHG mitigation needs of the country (Table 8). Intensification, manure management, and forage and fodder management are the primary livestock actions.

Table 8: Proposed actions that promote "synergies in adaptation and mitigation". The goals of these actions are to balance adaptation and mitigation 'without compromising productivity' (RoK 2018).

Promote adoption of low-cost climate smart technologies that minimize GHG emission and enhance removals
Promote low cost green energy for the agriculture sector
Promote efficiency in livestock production systems
Promote efficiency in paddy rice management
Promote appropriate livestock manure management
Promote formulation of feeds and feeds additives that improve efficiency and reduce enteric fermentation
Promote production of rain-fed rice to reduce emissions from paddy rice production systems
Develop and implement agricultural sector Nationally Appropriate Mitigation Actions (NAMAs)
Promote adaptation actions that have mitigation co-benefits
Minimize use of fires in rangelands and croplands management
Promote use of energy efficient technologies in production, harvesting, processing and transportation of agricultural inputs and products
Develop a national carbon accounting (NCA) system including establishment of monitoring, reporting and verification (MRV) infrastructure in the agriculture sector
Undertake capacity building on measurement of GHGs emissions; management of inventory system; data collection, reporting and verification in the agriculture sector

Key resources

FAO and NZAGGRC (New Zealand Agricultural Greenhouse Gas Research Centre). 2017. *Options for low emission development in the Kenya dairy sector - reducing enteric methane for food security and livelihoods*. Rome, Italy.

RoK (Republic of Kenya). 2018. *Kenya climate smart agriculture implementation framework 2018–2027*. Nairobi, Kenya: Ministry of Agriculture, Livestock, Fisheries, and Irrigation.

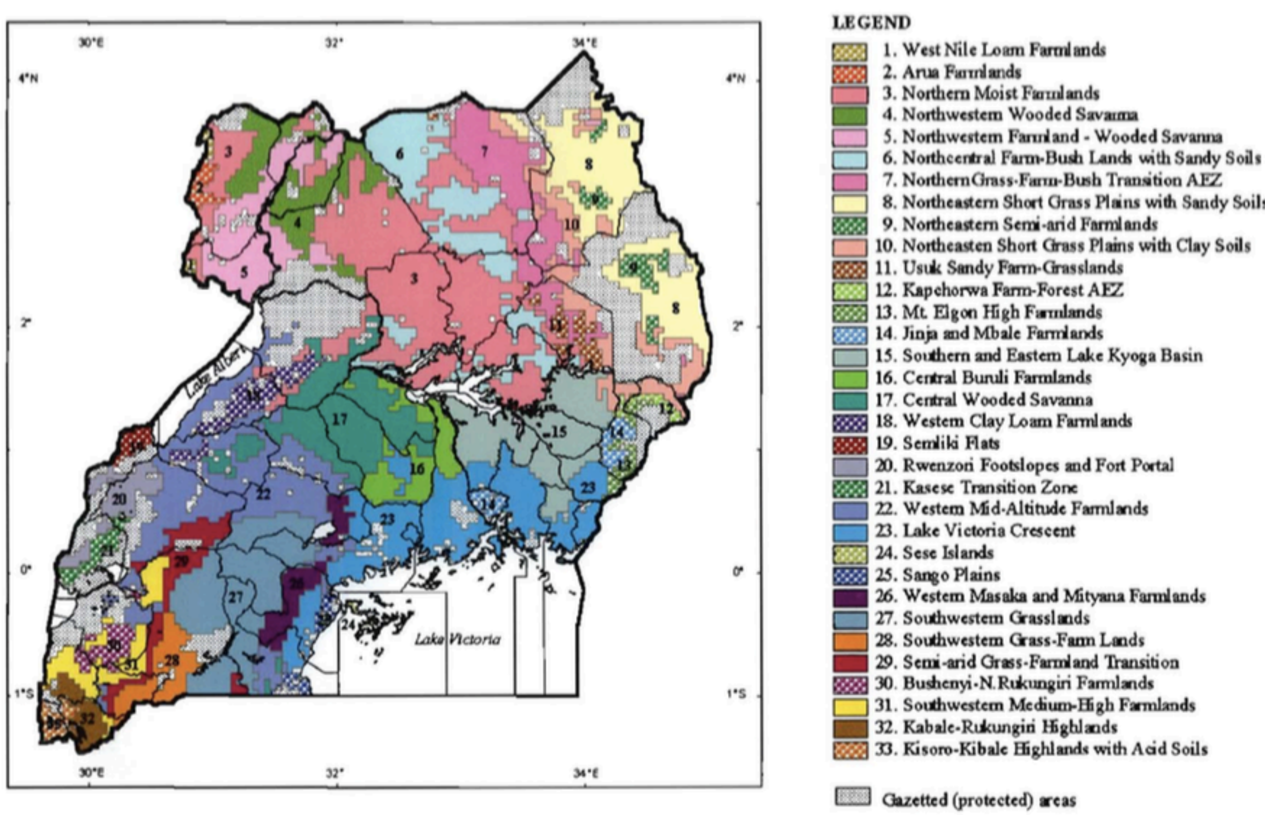
World Bank and CIAT. 2015. *Climate-smart agriculture in Kenya*. CSA Country Profiles for Africa, Asia, and Latin America and the Caribbean Series. Washington D.C.: The World Bank Group. https://hdl.handle.net/10568/69545

Uganda

Agricultural production and agroecological zones

In political terms four regions of Uganda are referenced: Northern, Central, Eastern, Western. These regions are broken into districts. One cluster of districts on the east edge of the North region is named Karamoja. Attempts to map the landscape by agroecological zones and production systems revel many micro regions that are parsed in different manners dependent on the framework or goal of the study. Early agroecological zone designation parsed 33 AEZs which were collapsed into 14 zones (Wortmann and Eledu 1999) (see figure 17 and 18). This 14 zone system is still used in some governmental reporting. However, a ten production zone classification produced by the MAAIF (2004) (see Figures 19 and 20) has become the basis for agricultural production planning at the governmental level (see in MAAIF 2016) and encouraged at the personal level.[18] In contrast to these broader ten categories of the MAAIF, the FEWS NET collaborative process distinguished 38 livelihood zones (see Figure 21).

Figure 17: Wortmann and Eledu's (1999) 33 agroecological zone map.



[18] For news announcement in 2009 regarding these zones as a basis for agricultural decision making see https://www.newvision.co.ug/new_vision/news/1250832/grow-agricultural-zone
and for promotion of these zones for investment planning see https://mofa.go.ug/cod/Agric_ProductionZone.html an online resource by the Ministry of Foreign Affairs, Uganda Investment Authority and UNDP titled "The Compendium of Diaspora Investment and Business Opportunities"

Figure 18: The aggregated map of 14 zones that is more frequently used. Maps from Wortmann and Eledu (1999).

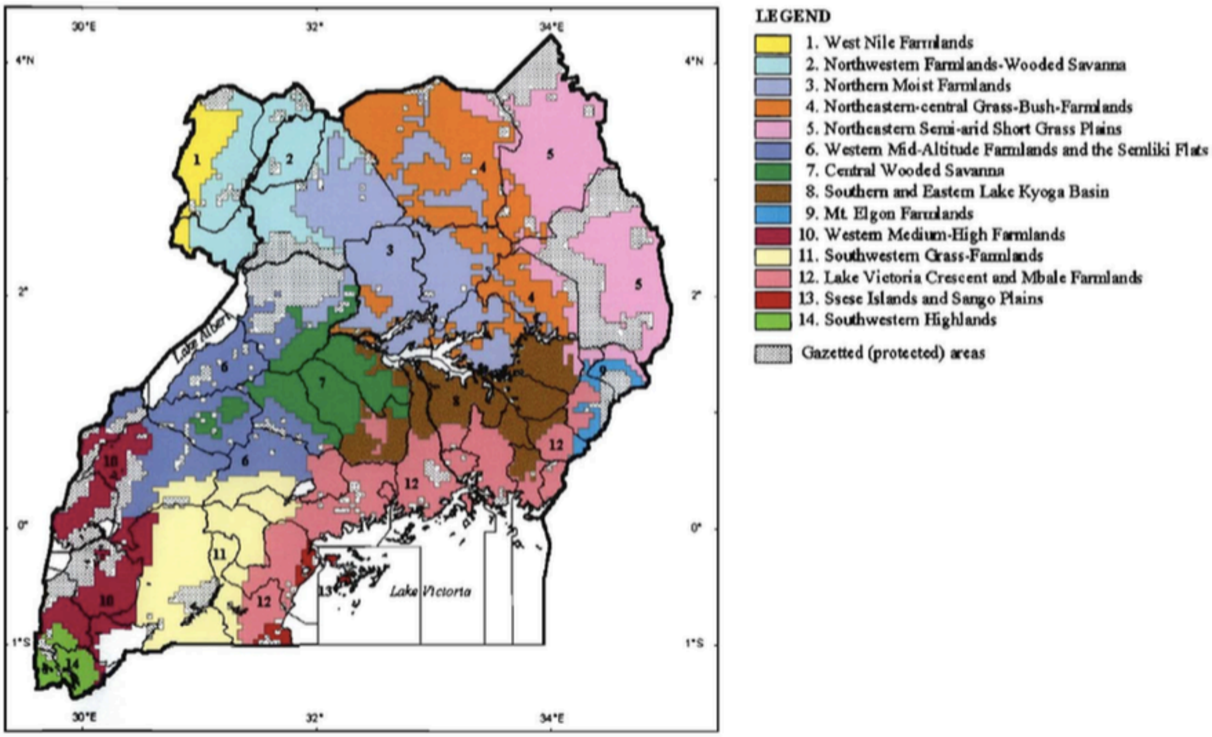


Figure 19: Ugandan ten production zone map as developed by MAAIF in 2004. Image from MAAIF (2016).

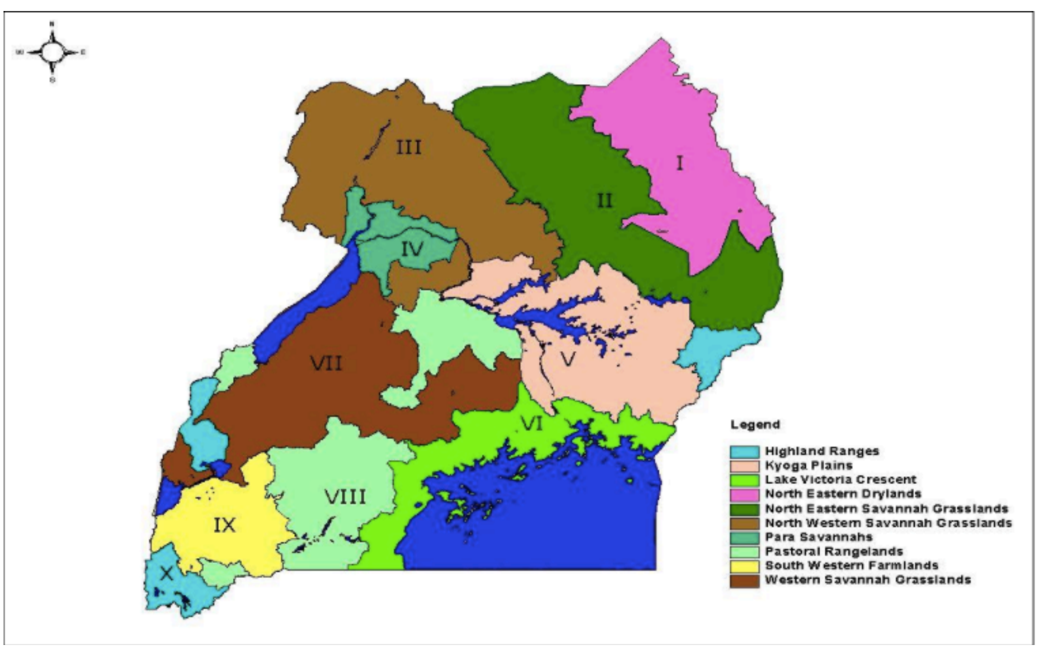


Figure 20: MAAIF ten production zone map with major agricultural sector production shown. Image from MWE (2015).

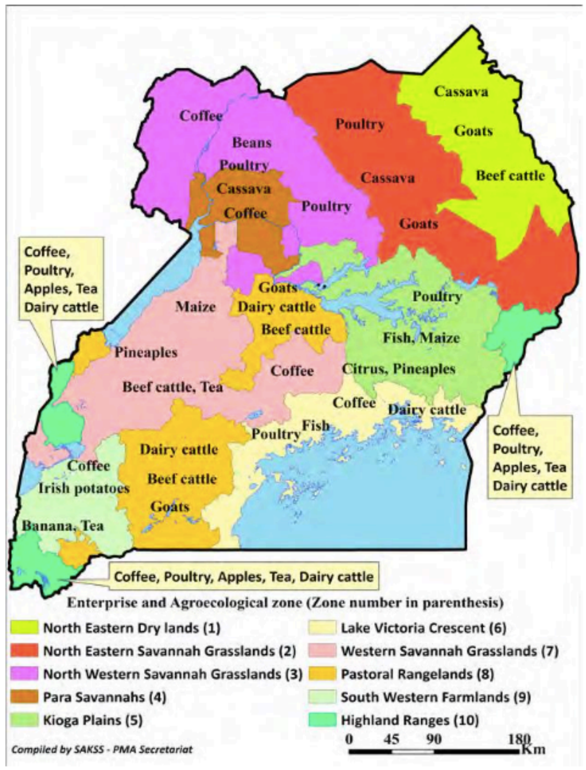
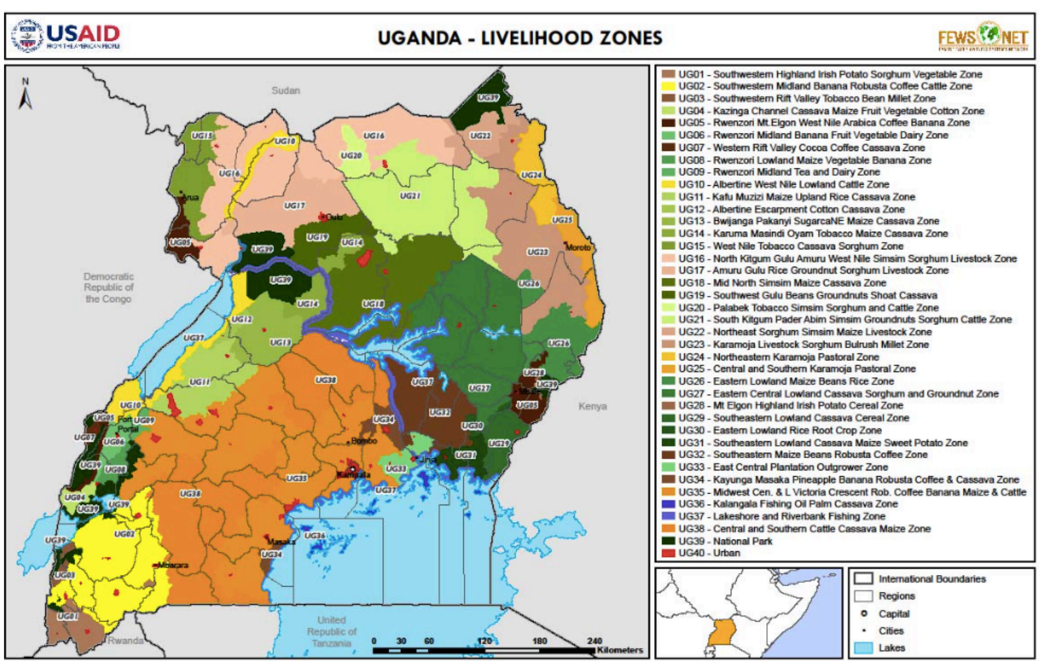


Figure 21: Livelihood zone map with 38 zones, which was collaboratively produced by government and NGO workers under FEWS NET leadership. Image from Brown and Glaeser (2010).



The agricultural sector is divided into food crops, cash crops, fishing, livestock and forestry. It is the major source of employment (66% of the working population or 73% total population) and contributes 40% to export earnings and 23.5% to GDP (UBOS 2016 and UBOS 2011). Though export earnings are driven by a few commodity crops, the food crop subsector dominates agricultural output; this sector alone is considered to be 14.6% of the GDP. This food crop production is predominantly done by smallholders (<2 hectares of land) and is rain fed. This production is subsistence oriented but can include small scale engagements with cash crop production. There are a range of food crops, but cereals (of which maize alone is 63%) and starchy crops are predominant in the production and in the diet (attributing to what can be caloric sufficient but micronutrient poor dietary practice, FAO 2010).

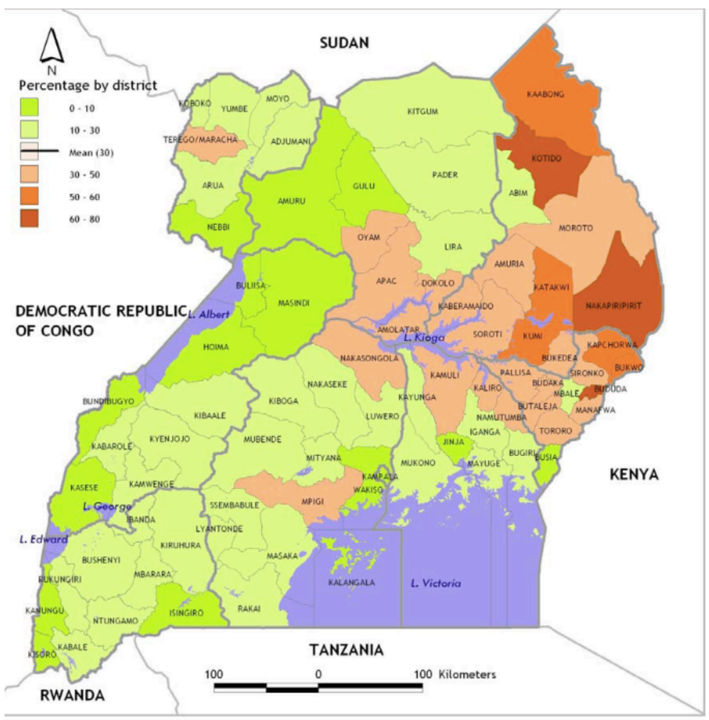
In these smallholder households, livestock are important. The 2008 livestock census found that 70.8% of households have at least one kind of livestock (including poultry) and household labour is the main source for livestock care. Only 2.4% of households have livestock labour hires, indicating smallholder, non-intensive systems. Smallholders are calculated as owning 80% of the national livestock herd. Livestock production is dominated by cattle, sheep, goats, pigs and poultry, though apiculture is being encourage. A national livestock census was last run in 2008 by the Ministry of Agriculture, Animal Industry and Fisheries and The Ugandan Bureau of Statistics. The UBOS has subsequently estimated the national herd in 2017 to be 14,189 million cattle, 16,034 million goats, 4,445 million sheep, 4,109 million pigs and 47,579 million chickens (UBOS 2018).

The value of livestock in smallholder systems has likely been underestimated, due to the chronic undervaluing of non-market values of livestock in household economies (Moll 2005). For example, a review of the poultry production in Uganda found 36% of chickens are self-consumed, 33% are sold for cash, 16% are used for ceremonies, 13% are given away as gifts and 2% are used for other purposes (Ssewannyana et al. 2008). Livestock system valuation needs to consider these non-nutritive, non-market values the animals have in a smallholder household. However, for Uganda, even with such a re-valuation of the livestock sector, food crops remain the most important agricultural product (ICPALD 2013). In this revaluation, the conclusion was that the livestock sector contributed 3.2% of the GDP in 2009 (against the official estimate of 1.7%); the report states 'to put the revised livestock contribution into perspective, it is larger than the GDP derived from either cash crops or fishing, marginally smaller than the contribution from forestry, but still only about a quarter of the value of food crop production' (ICPALD 2013).

The 2008 livestock survey found that 26.1% of households own cattle, with the percentage of households owning cattle unequally distributed across the country (see Figure 22). The major livestock production systems in Uganda are pastoral and agropastoral, but some commercial ranching and semi-intensive (dairy) cattle production exists. Mwebaze et al. (2011) characterize the production zones of Uganda as: semi-intensive production is mainly located in Central 1, Central 2, south western sub regions, and in peri-urban areas; agropastoralists are present in the East, Central, mid western, mid eastern, mid northern and west Nile regions; and the pastoral system is dominant in the north eastern sub region (the drylands) but is also found in central Uganda and the southwest sub region (Mwebaze et al. 2011). This sweep of pastoralism and agropastoralism from south-western to north-eastern Uganda in the drier zones is often called the "cattle corridor".

Although total cattle holdings are estimated to have increased by 54% since 2005, current production levels only meet half the domestic and regional demand (Mbowa et al. 2012). The interest in the agricultural sector is being directed toward increasing overall productivity. The chicken meat and beef production capacities of the nation are targeted priorities for the MAAIF (FAO 2018). In the dairy sector, smallholder production currently supplies the majority of the milk sector, but even therein only 34.7% of milk production is sold (MAAIF and UBOS 2009). The dairy sector is capable of expansion and intensification (Balikowa 2011; Tijjani and Yetişemiyen 2015). But also, in keeping with the value of smallholder systems in Uganda, the President has made a directive to provide one heifer per household that is being incorporated into the national Agriculture Sector Strategic Plan.[19] Moreover, the national goal is for significant growth in its cattle numbers up to 40 million by 2030 (MWE 2014).

Figure 22: Percentage of household that own cattle by district. Note that the north eastern region of Karamoja has the fewest number of cattle owning households, but the region has the highest percentages. Image from MAAIF and UBOS (2009)



Key resources

ICPALD (IGAD Center for Pastoral Areas & Livestock Development). 2013. *The contribution of livestock to the Ugandan economy*. Policy Brief 7/CLE/8/2013.

FAO. 2018. *Livestock production systems spotlight: Uganda: Chicken meat and beef.* Africa Sustainable Livestock 2050. Report I8713EN/1/02.1

[19] The Agriculture Sector Strategic Plan (ASSP) https://www.agriculture.go.ug/agriculture-sector-strategic-plan-assp/

FAO and NZAGGRC (New Zealand Agricultural Greenhouse Gas Research Centre). 2019b. *Options for low emission development in the Ugandan dairy sector - reducing enteric methane for food security and livelihoods*. Rome, Italy: FAO.

Mwebaze, S.M., Suttie, J.M. and Reynolds, S.G. 2011. *Country pasture/forage resource profiles: Uganda.* Rome, Italy: FAO. (Available from https://docplayer.net/65877808-Country-pasture-forage-resource-profiles-uganda-by-sandra-m-n-mwebaze.html) (Accessed 29 January 2020)

Food and nutrition security

Uganda is considered a food secure country, but this food security varies considerably across regions (MAAIF 2010). In most regions of the country food is adequately available and reasonably priced. Local production of staple cereals and starches meets demand and is sufficient to last to the next harvest period. Nationally, import levels of staples are very small (though this has been rising). The World Bank classifies Uganda as a high commodity export and low commodity import economy (FAO et al. 2019), but world food prices still have food security implications for Ugandan population (Benson et al. 2008). 60% of rural households are still net buyers of food despite many being smallholder producers themselves. Despite the relative abundance of local food crops, nationally, PoU is 41%, with a prevalence of wasting in children at 3.5% and prevalence of stunting at 38.9% (FAO et al. 2019). Uganda also has a relatively high population in poverty (31.1 % at less than < 2 USD/day) (UBOS 2011/2012). Also, dietary diversity can be limited, and this leads to problems with malnutrition due to micronutrient insufficiency even in areas with high crop productivity (Ssewanyana and Ahmadi-Esfahani 2001).

Despite having portions of the country with good agricultural production, the drier northern and northeast regions suffer from chronic food insecurity. For example, in the year of 2015 while 89% of the country was deemed food secure, 11% of the population in the Acholi, Teso and Karamoja regions suffered acute drought induced food insecurity. The chronic food insecurity in the region is often blamed on the general failure of pastoral production, but such judgements fail to take in account the historic dispossession and social exclusion which undermined the pastoral systems in the first place (Levine 2010). Regional conflict and an influx of refugees from neighbouring countries have also added to food insecurity in the north. Ongoing droughts and regional violence are expected to continue to exacerbate the food insecurity in the region.

Key resources

FAO. 2010. *Uganda nutrition profile 2010*. Rome, Italy: Nutrition and Customer Protection Division, FAO.

Levine, S. 2010. *What to do about Karamoja? Why pastoralism is not the problem but the solution*. A food security analysis of Karamoja, Uganda. FAO and ECHO.

MAAIF (Ministry of Agriculture, Animal Industry and Fisheries). 2010. *Agriculture for food and income security: Agriculture Sector Development Strategy and Investment Plan, 2010/11–2014/15*. Kampala, Uganda: MAAIF.

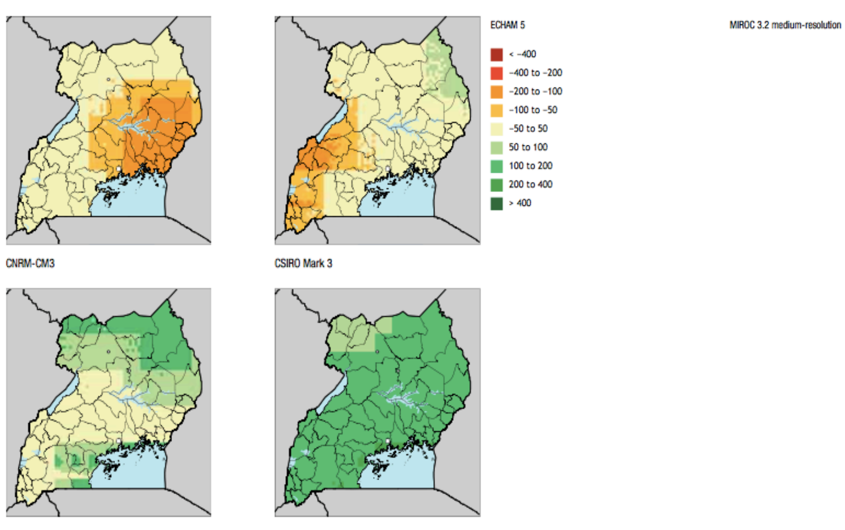
Climate change

The climate of Uganda has cross country variation with dry savannas to the north, drier, arid lands in the northeast, tropical but with lake affected monsoon climates in the centre and semi-humid conditions in the southeast. In central and southern Uganda, the climate has a distinct bimodal rain cycle driven by the ITCZ. Historically these rains are considered the long rains in the March to May period, and the short rains from October to December. ENSO events can increase the amount of rain that falls in the short rains. The northern portion of the country trends toward unimodal rainfall patterns. Climate trend data from meteorological stations show an increase of 1.3°C in mean annual temperature since 1960, with increases in hot day and hot night frequency and a significant decrease in cold days (McSweeney et al. 2010). Rainfall patterns over the same time period show a statistically significant decreasing trend, of 3.4mm per month per decade. The declines are heaviest in the March to May rains (McSweeney et al. 2010).

The McSweeney review of climate change models for Uganda says all models agree that the future will be hotter with more 'hot' days, more 'hot' nights and fewer cold days; the only difference in any of the models is in the number of degrees of increase (a range of 1 to 3.1°C by 2030). In Bashaasha et al. (2013) they reviewed four models and found temperature predictions for 2050 to range from "only slightly warmer" to 2.5°C.

The McSweeney and Bashaasha reviews are similarly unclear in the precipitation trends. McSweeney et al. (2010) state boldly 'projections of mean rainfall are broadly consistent in indicating increases in annual rainfall. The ensemble range spans change of -8 to +46% by the 2090s'. Bashasha et al. (2013) are less certain in predicting rain increases, their four model scenarios 'seem quite diverse'. One projects a dryer future in the east and north east (the CRNM-CM3), while the CSIRO Mark 3 projects rainfall declines in the southeast. In contrast the MIROC 3.2 projects wetter conditions for the whole country (see Figure 23).

Figure 23: Four different future scenarios for average precipitation for Uganda based on different Global Circulation Models. Image from Bashaasha et al. (2013); data credit given to Jones, Thornton and Heinke (2009).



A review of climate changes potential impacts in Uganda lists a number of outcomes: loss of agricultural production through flood, drought or heat stress; pest outbreaks that destroy standing or stored crops; declining fish stocks in Lake Kacyera and the river Rwizi due to decreases water quality, loss of rangeland with plant community changes toward unpalatable plants (Nuwagaba and Namateefu 2013). A trade-off analysis model concluded that 70–97% of households will be adversely affected by climate change in Uganda, with the impacts most strongly felt by smallholders (Bagamba et al. 2012). Some crop yields could increase with climate change due to expansion of suitable land but increase in diseases (like the already emerged banana bacterial wilt and the African cassava mosaic virus) coupled with heat stress could eliminate much of the yield gains (Bashaasha et al. 2013). See USAID 2013 for a review of climate change impacts on crops and analyses of population vulnerabilities to climate change.

Key resources

Bashaasha, B., Thomas, T.S., Waithaka, M. and Kyotalimye, M. 2013. Uganda. In: Waithaka, M., Nelson, G.C., Thomas, T.S. and Kyotalimye, M. (eds), *East African agriculture and climate change: A comprehensive analysis*. Washington, D.C.: International Food Policy Research Institute (IFPRI): 347–375. (Available from http://www.ifpri.org/publication/uganda) (Accessed 29 January 2020)

MWE (Ministry of Water and Environment). 2015. *Economic assessment of the impacts of climate change in Uganda*. National level Assessment: Agricultural Sector report. March 2015.

McSweeney, C., New, M. and Lizcano, G. 2010. *UNDP climate change country profiles: Uganda*.

USAID. 2013. *Uganda: climate change vulnerability assessment report*. Kampala, Uganda: USAID.

GHG emissions and livestock

Uganda submitted its Second National Communication (SNC) in 2014 and its INDC in 2015. The national GHG inventory was published in the SNC utilizing the year 2000 as its base. In this review it was determined that domestic livestock were the largest contributor to the agricultural sector (89%) and then flooded rice cultivation (8%). Other agricultural contributions came from soils, field burning of agricultural residues, and prescribed burning of savannahs. Uganda calculated its contribution on Tier 1 methods (MWE 2014).

Updated emissions numbers from 2012 put the total GHG emission for Uganda at 49 Mt CO_2e, or just 0.10% of the world total. The agricultural sector is the main GHG emitter (48% of total), followed by land use change and forestry (38%). Enteric fermentation is the major source of agriculture emission at 11 Mt CO_2e per year and manure left on pasture also contributed around 9 MtCO_2e per year. The primary drivers or the agriculture sector emissions are livestock production, inefficient animal waste management, and pasture management systems (USAID 2015). A detailed study of the dairy sector in Uganda has found that dairy emissions rates vary between production systems. Traditional dairy production accounts for 86% of the milk and 97.2% of the emissions, conversely commercial production contribute 14 % of the milk and 2.8% of the emissions. As most of the traditional production is in agropastoral (mixed crop-livestock) this sector accounts for the most absolute emissions (Figure 24). Conversely, when looking at emission per unit of production, pastoral systems produce the most (Figure 25).

Figure 24: Emissions by production systems (FAO and NZAGGRC 2019)

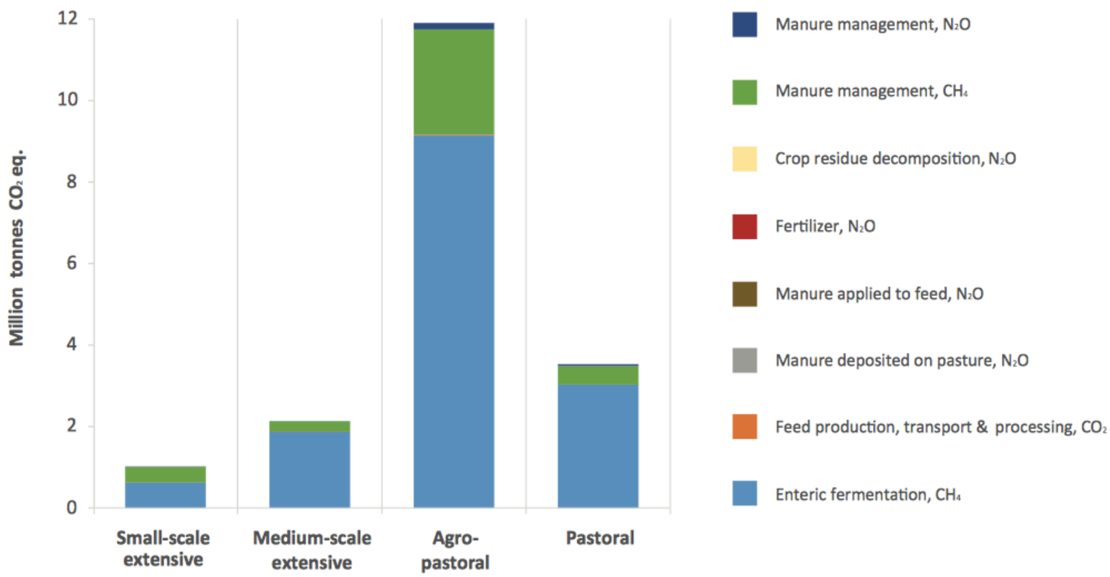
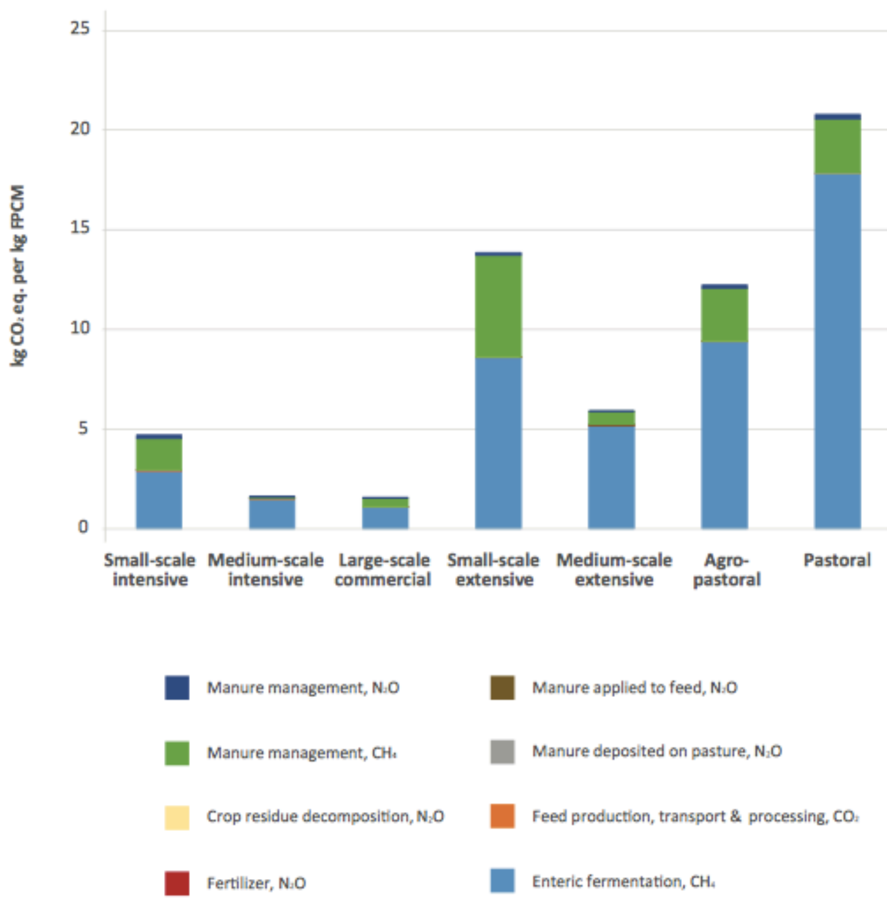


Figure 25: Emissions intensities by production system (FAO and NZAGGRC 2019)



Key resources

MWE (Ministry of Water and Environment). 2014. *Uganda second national communication to the United Nations Framework Convention on Climate Change*. October 2014.

USAID. 2015. *Greenhouse gas emission in Uganda*. (Available form https://www.climatelinks.org/resources/greenhouse-gas-emissions-factsheet-uganda) (Accessed 29 January 2020)

Climate-smart livestock

Uganda set mitigation goals in its second NDC that targeted the livestock sector, more than the agricultural sector, as having high potential for mitigation actions. Key goals set were for migration through improved animal health and manure management (MWE 2014). Following on this, the INDC (2015) developed a formal set of adaptation plans and expanded its goals for the agricultural sector. The agricultural sector priorities include research, institutional service provisions, diversification, land management, water infrastructures, value addition, and the general adoption of CSA practices (see Table 9). In keeping with the perceived value of CSA the government published in that same year the Uganda National Climate-Smart Agriculture Programme (2015–2025) the goals of which are:

- Increase agricultural productivity through climate-smart agricultural practices and approaches that consider gender;
- Increase the resilience of agricultural landscapes and communities to the impacts of climate change;
- Increase the contribution of the agricultural sector to low carbon development pathways through transformation of agricultural practices;
- Strengthen the enabling environment for efficient and effective scaling up of CSA;
- Increase partnerships and resource mobilization initiatives to support implementation of CSA.[20]

The CSA plan lays out target goals similar to the INDC, which include: increased adoption of CSAs, value chain improvements, and post-harvest loss reduction, and micro irrigation. Targets with direct livestock, and climate-smart livestock, relevance include increased productivity of the urban and peri-urban areas (by +30%), market output of food and cash crops, livestock and fisheries (+50%), and silvopasture increased (+20%).

[20] CSA goals copied from https://www.slideshare.net/cgiarclimate/the-way-forward-for-ugandas-csa-program-2015-2025

Table 9: The Priority Adaptation Actions for agriculture (INDC 2015)

Priority Sectors	Priority Adaptation Actions
Agriculture	Expanding extension services
	Expanding climate information and early warning systems
	Expanding Climate Smart Agriculture (CSA)
	Expanding diversification of crops and livestock
	Expanding value addition, post-harvest handling and storage and access to markets, including micro-finances
	Expanding rangeland management
	Expanding small scale water infrastructure
	Expanding research on climate resilient crops and animal breeds
	Extend electricity to the rural areas or expanding the use of off-grid solar system to support value addition and irrigation.

This national interest in CSA practices has enabled an environment of climate-smart adoption and experimentation in Uganda. FAO (2016) lists project types that have been deployed in Uganda: these include: conservation agriculture, agroforestry, water harvesting for crops and livestock, soil and water conservation practices, integrated soil fertility management, livelihood diversification, biogas and biomass fuel production. Kipkoech et al. (2015) also overviews Ugandan CS activates and notes that the majority have been in crop and water-based projects. Kipkoech et al. cover successful silvopasture projects as the main livestock CS project. The FAO (2016) is similarly terse on specific climate-smart livestock practices, other than general livelihoods diversification, the main livestock CS potential is in reference to the pursuit of improved crop and livestock breeds.

Thus, though CSA is being promoted and adopted in Uganda there is still much potential for the expansion of an explicit climate-smart livestock focus. In the comprehensive CSA Country Profile, the introductory overview states: 'in livestock production, CSA practices that have been promoted include silvopastoral systems, adoption of improved breeds, improved feeding regimes, grazing land management and integration of biogas. Since, livestock production encompasses the highest contributor of agricultural GHG emissions in Uganda, these and other livestock-based practices present good opportunities to reduce agricultural emissions in the country' (CIAT; BFS/USAID. 2017) (emphasis added).

The major current focus of livestock development is on cattle, in particular the dairy sector and the extensive pastoral systems, as both of these systems are seen as having high potential for mitigation. Because of this interest in mitigation, opportunities for win-win-win scenarios through climate-smart livestock practices should be perused. Potentials climate-smart work is discussed below for three different cattle systems.

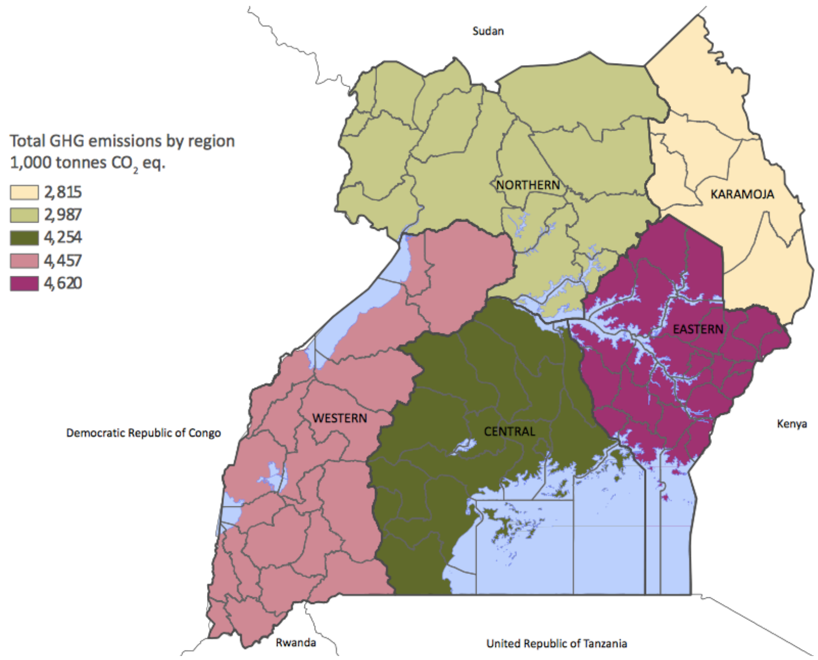
Pastoral and agropastoral production systems:

Pastoralists keep herds that can be as big as 100 head per person, with the majority of the herds (98%) being local breeds (Mwebaze et al. 2011). The conditions of extensive grazing and low productivity rates (re. milk production and offtake) make the pastoral and agropastoral production systems rank high in emissions rates. However, Levine's (2010) review of production and livelihoods in the Karamoja region concludes that pastoral production is the best option for the area, and in fact, during the last droughts pastoralists required less assistance than crop-based livelihoods. Climate-smart livestock goals should include intensification of management through support for selective breeding, improved animal health and rangeland improvement techniques that can be implemented while also facilitating continued pastoral practices.

Semi-intensive cattle meat production:
This system comprises less than 10% of the national herd. In this system cattle are kept in a confined shed or in a paddock. Fodder, compound feed and crop residues constitute the main feed sources (ACET 2014). In most cases, the animals are crossbreeds of East African Zebu and Holstein Friesian. Semi-intensive systems are among the most efficient in Uganda, particularly when well integrated with crops; however, animal productivity is stiller lower than potential as access to feeds and veterinary services (in particular breeding services) is still limited (ACET 2014). With support for veterinary services, ensuring proper fodder and forage and market access these semi intensive systems have much potential as climate-smart livestock systems in Uganda. This is particularly true if manure management, whether for crop fertility or biogas production is pursued alongside the system intensifications.

Dairy production:
There are four major dairy production systems; free range grazing, paddocked, communal grazing, and zero grazing (Ekou 2014) and the scale and GHG emissions from these are not uniformly distributed around the country (see Figure 26). Smallscale farmers dominate Uganda's dairy production owning over 90% of the cattle population in the country (MAAIF and UBOS 2009). Feeding structures vary across these smallholder systems, though opportunistic grazing, cut and carry, and crop residue feeding are common. Overall the dairy sector productivity operates at less than full animal potential (FAO and NZAGGRC 2019) and support for intensification of smallholder practices has mitigation potential for the nation. Climate-smart livestock programs should target veterinary services, improved fodder and forage production and access, and manure management techniques that can be leveraged for the productivity goals of the mixed crop-livestock system that currently house a preponderance of the national herds.

Figure 26: Total GHG emissions per region from the dairy production sector in Uganda. Image from FAO and NZAGGRC (2019b)



Alongside these cattle-based CS activities, attention should be given to finding the "other" livestock opportunities as mentioned in the CSA country profile. In the arid Karamoja region camel based systems could be expanded. Poultry systems are also being targeted for intensification and expansion in the urban and peri-urban areas (FAO 2018) and overall capacities for meat production are part of the strategic goals for the agricultural sector (MAAIF 2016). Opportunities for innovative climate-smart work in small ruminant, poultry, apiculture and fisheries should be pursued in order to present a fuller suite of climate-smart livestock technologies as possibilities for deployment in this receptive policy environment.

Key resources

CIAT and BFS/USAID. 2017. *Climate-smart agriculture in Uganda*. CSA Country Profiles for Africa Series. Washington, D.C.: International Center for Tropical Agriculture (CIAT) and Bureau for Food Security, United States Agency for International Development (BFS/ USAID). (Available from https://ccafs.cgiar.org/publications/climate-smart-agriculture-uganda#.XbvxZSVS87Y) (Accessed 29 January 2020)

MAAIF (Ministry of Agriculture, Animal Industry and Fisheries). 2016. *Agriculture sector strategic plan*. 2015/16–2019/20. Draft. April 2016.

MWE (Ministry of Water and Environment). 2015. *Uganda's intended nationally determined contribution (INDC)*. October 2015.

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Njeru, E., Grey, S. and Kilawe, E. 2016. *Eastern Africa climate-smart agriculture scoping study: Ethiopia, Kenya and Uganda*. Addis Ababa, Ethiopia: FAO.

Rwanda

Agricultural production and agroecological zones

Rwanda is known for its high elevation landscape with extreme topographical diversity. An east west gradient from high plains to humid montane regions exists (see Figure 27). Within this range of landforms Rwanda can be divided into ten agroecological zones (see Figure 28). However, a more nuanced GIS based land use map was developed at a collaborative workshop in 2010 (Kagera TAMP 2010) (see Figure 29). This level of detail is important for agricultural planning, especially in regard to cropping systems. Cropping systems in Rwanda are diverse as the climate and soil types vary considerably, and soil erosion is a major concern in this 'land of a thousand hills.' FEWS NET has also developed a livelihood zones map for Rwanda and provides detailed production reviews for each zone (see Figure 30). Livestock planning has been done at a much coarser scale. For the current livestock system master plan (see in Shapiro et al. 2017) a rainfall and altitude zonation is used, which generates three zones: Low rainfall, low altitude livestock production zone (LRLA), this is the far east of the country, including its border with Tanzania and some of its border with Uganda; Medium rainfall, medium altitude livestock production zone (MRMA), is the middle of the country, and high rainfall, high altitude livestock production zone (HRHA), is the far west.

Figure 27: Physical landscape of Rwanda, demonstrating the east to west differentiation of the landforms. Dotted orange line marks the major watershed divide. Image from Henninger (2013)

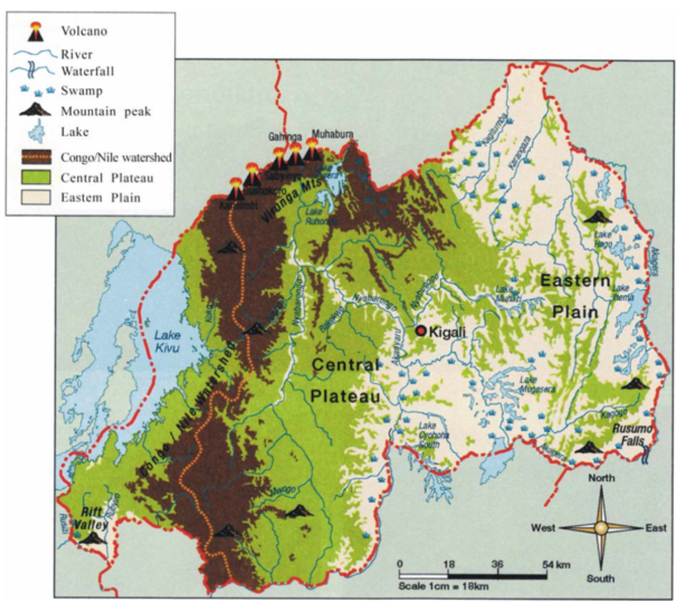


Figure 28: 10 Agroecological zones. Produced by MINAGRI in the 1980s. Image from Kagera TAMP (2010)

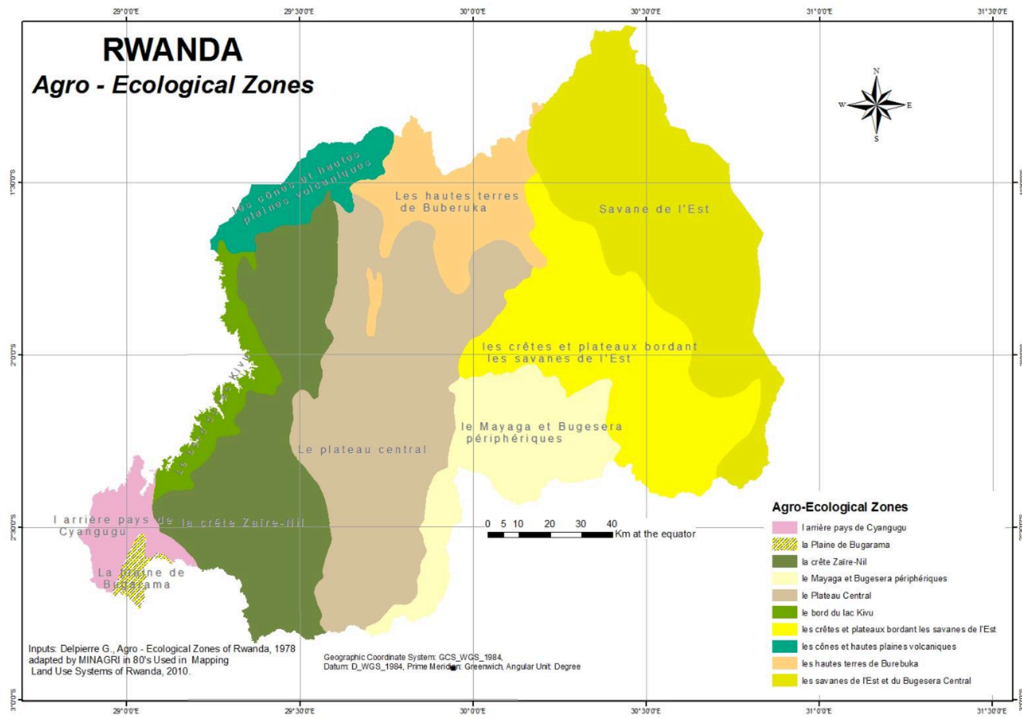


Figure 29: Reclassified land use map generated through Rwandan resource mapping workshop in 2010. Image from workshop document Kagera TAMP (2010)

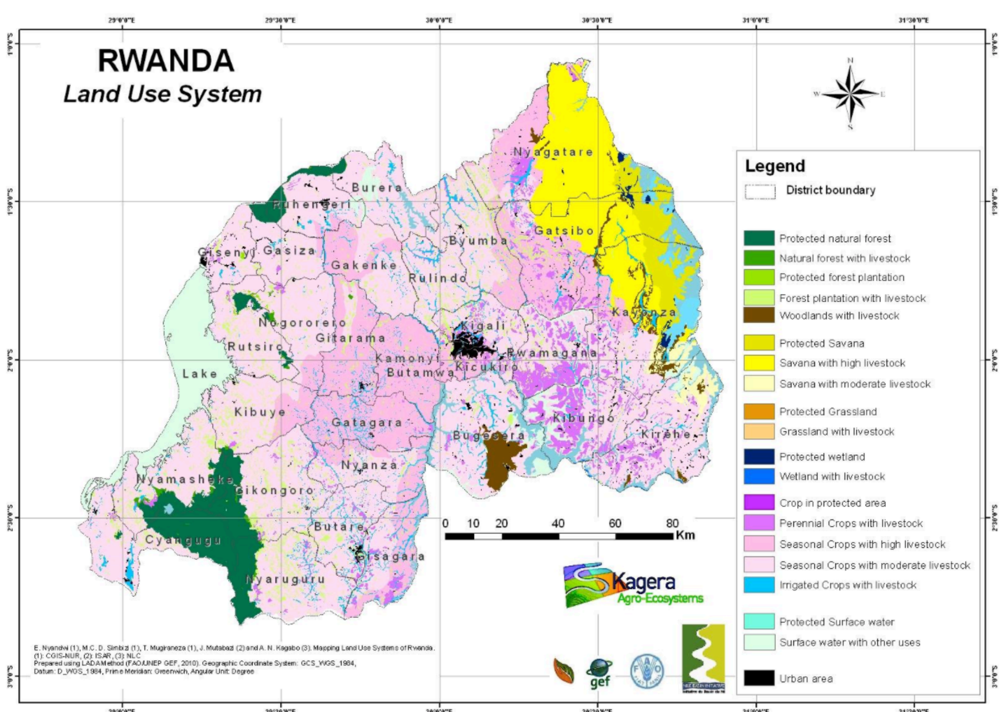
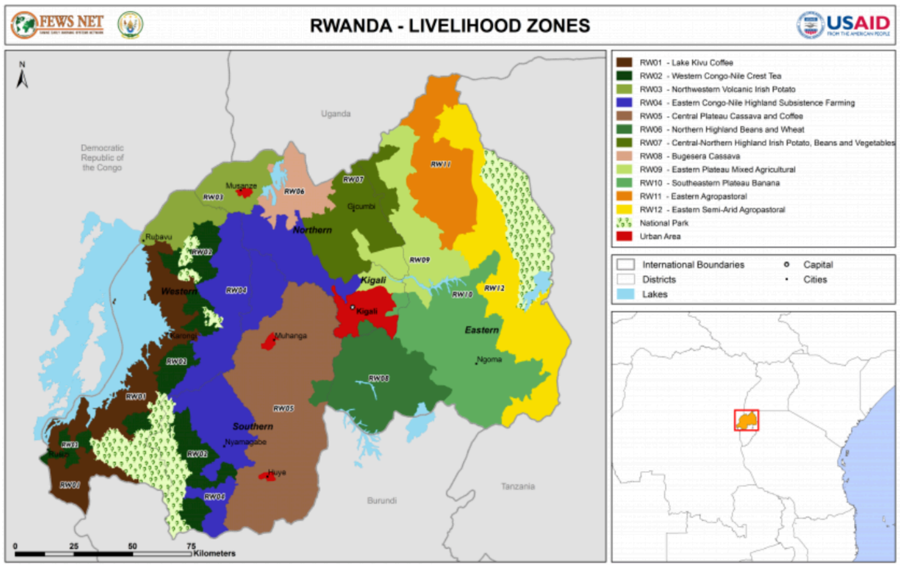


Figure 30: Rwandan livelihood zones, FEWS NET developed zone map from 2012. Image from http://fews.net/east-africa/rwanda/livelihood-zone-map/july-2012



Agriculture is 30% of the national GDP and provides almost 50% of Rwanda's export trade (coffee and tea predominate) (MINAGRI 2009). Subsector contributions to agricultural GDP are: food crops (58%), forestry (21%); livestock (12%); traditional export crops (7%); and fisheries (1%) (MoE 2019). But despite agriculture being only 30% of the formal economy, the standard rubric is that 70 to 80% of the Rwandan population has a livelihood base in agriculture; moreover, the agricultural sector is said to employ between 70 and 92% of the population. This is mainly through smallholder (very small, estimated average land holding is less than 0.59ha), rain fed mixed crop-livestock households. NISR (2013) data states that agricultural production households are distributed as 66.6% crop and livestock, 32.8% only crop, and 1% only livestock (data referenced in Gasheja and Gatemberezi 2017). A high population density and limited land mass constrains farming and livestock production and the small size of average landholdings makes the smallholder system insufficient to meet household needs. (See Gasheja and Gatemberezi 2017; FEWS NET 2015 and Tenge et al. 2013 for overviews of agricultural crop production by region and type).

The livestock sector in Rwanda is almost entirely comprised of mixed crop-livestock production linked to smallholder households. The NIS for Rwanda calculate around 70% of all households in Rwanda own some type of livestock (NISR 2012). The national livestock herd consists of 1.39 million cattle, 700 thousand sheep, 2.94 million goats, 1.8 million pigs and 7 million layers, broilers and indigenous chicken (data from Shapiro et al. 2017). For indications of how these livestock are distributed compare the total numbers to household ownership from 2010 data for rural households: having goats (53%), cattle (47.3%), chickens (5.5%), and pigs (24.1%). For the poultry sector there are 7 million animals in only 5.5% of the households, this indicates that intensification has start to take hold in the poultry sector.

Cattle numbers are low compared to other species in the country and especially when compared to neighbouring countries. This is one of the legacies of the 1990s genocide. During the violence cattle were slaughtered; some to meet food needs in the conflict induced food shortages, but cattle were also slaughtered in the intentional targeting of perceived Tutsi people and their livelihood base.[21] Attempts to reintroduce cattle into household production started in the early 2000s with NGO activities to supply cattle and other livestock to impoverished households (IFRC 2016). A Government program called Girinka (One-Cow per Poor Family Programme) has integrated and followed on these projects and has been in operation since 2006. Girinka has been distributing cattle, education and technologies for animal nutrition, animal breeding, and disease control. Programmatic emphasis has been on exotic and crossbreed animals; cattle distribution is limited to landed households who would be able to provide provisioning through zero-grazing methods.

The importance of the cow as a cultural symbol, especially the dramatic Ankole breed, has had implications for efforts of other meat and dairy augmentation strategies. Indigenous cattle still outnumber exotic and cross breeds, but cross breeds are becoming recognized and valued by smallholders for their higher milk productivity (see Table 10). Compared to neighbouring countries Rwanda has a high pig population and has traditional practices of pig rearing but goat milk use is negligible in Rwanda and sheep production has no historic practice in the country (Shapiro et al. 2017). Attempts to provision with a goat instead of a cow (based on landholding and judgements about the household's ability to sufficiently provision a cow) were met with resistance.[22] Overall, cattle are the preferred livestock, and red meat (cattle and then goat) the preferred meat. Policies to increase poultry production and consumption will need to overcome these preferences.

Dairy production value chains are increasingly showing diversification into exotic breeds and into more intensive production systems but herd sizes in dairy production are still small: an average of seven cows, with two lactating, in the extensive system and only an average of 2.6 cows, with 1.7 lactating in mixed, semi-intensive households (Grewer et al. 2016). Shapiro et al. classify dairy production into two main categories, Improved family dairy (IFD) and commercial specialized dairy (CSD) and describe them as:

> The IFD production system is practiced by farmers in mixed crop-livestock production systems, uses crossbred cattle with small level of inputs and results in a moderate level of milk production. The CSD system, on the other hand, is a commercial scale specialized dairy production system. It includes the specialized grazing based dairy production that is mainly practiced in the Gishwati Rangeland and non-grazing based dairy production that is practiced mainly around urban and per-urban areas (Shapiro et al. 2017).

In the livestock master plan the four value chains of dairy (cattle only), cattle meat, poultry and pork are all identified as having great potential for expansion but will require targeted investment from both internal and external funding streams (Shapiro et al. 2017).

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[21] https://reliefweb.int/report/rwanda/feature-rwanda-cattle-herd-becomes-symbol-recovery-after-genocide, claims 90% of the cattle were killed.

[22] https://www.ifad.org/es/web/latest/story/asset/39129109

Table 10: Distribution of cattle types in rural and urban households. % is from total households in country, # is total head count. Note how the exotic breeds are almost exclusively found in the 'urban category.' Data from http://rwanda.opendataforafrica.org/gallery/Livestock; data numbers credited to 2012 census data[23,24].

Cattle type		Total	Urban	Rural
Local breed	%	19.3	6.6	22
	#	1,256,838	201454	1055384
Cross	%	12.7	6.1	14
	#	605727	90078	515646
Exotic	%	3.4	3.3	3.4
	#	189706	57673	132033

Key resources

FEWS NET. 2015. *Rwanda livelihood zones and descriptions*. USAID and FEWS NET.

Gasheja, F. and Gatemberezi, P. 2017. *An assessment of Rwanda's agricultural production, climate change, agricultural trade and food security*. KIPPRA Working Paper No. 23. Rural Development Department, Kigali International University. (Available from https://repository.uneca.org/handle/10855/24199) (Accessed 28 January 2020)

Shapiro, B.I., Gebru, G., Desta, S. and Nigussie, K. 2017. *Rwanda Livestock Master Plan*. Nairobi, Kenya: ILRI. https://hdl.handle.net/10568/104049

Food and nutrition security

WFPs 2018 insecurity and vulnerability analysis concludes that 81.3% of Rwandan households can be considered food secure, and 18.7 % are food insecure (which can be subdivided into 17% moderately and 1.7% severely food insecure). However, food insecurity in Rwanda is highly variable in space and time. The western province ranks highest in 2018 on food insecurity but this belies the great improvements that have occurred there in the last three years, while at the same time food insecurity in the east has deteriorated markedly (see Table 11).

[23] Total cattle population from this data set implies a cattle head count of 2,052,271, which is much larger than the Shapiro et al. 2017, cattle head count of 1,39million attribute to 2016/17 data. Other livestock reviews report cattle count in the 1 million rather than 2 million range: Gasheja and Gatemberezi 2017 report livestock counts for 2013 of (in millions) cattle 1,132; Sheep .798; goats 2,702, pigs 1,011; rabbits 1,106; and poultry 4, 803 (data credited to RAB/ Animal Resource Extension. Note the difference too in the poultry numbers between Shapiro (7 million and G&G (4.8 million).

[24] Total cattle population from this data set implies a cattle head count of 2,052,271, which is much larger than the Shapiro et al. 2017, cattle head count of 1,39million attribute to 2016/17 data. Other livestock reviews report cattle count in the 1 million rather than 2 million range: Gasheja and Gatemberezi 2017 report livestock counts for 2013 of (in millions) cattle 1,132; Sheep .798; goats 2,702, pigs 1,011; rabbits 1,106; and poultry 4, 803 (data credited to RAB/ Animal Resource Extension. Note the difference too in the poultry numbers between Shapiro (7 million and G&G (4.8 million).

Table 11: Food insecurity percentages by livelihood zone in 2015 and 2018 (WFP 2018)

Livelihood zone	2015 Food insecure	2018 Food insecure	Variation 2018/2015
Kigali city	2.9%	2.0%	-1.0%
Lake Kivu Coffee Zone	37.3%	27.4%	-9.9%
West Congo-Nile Crest Tea Zone	49.1%	35.8%	-13.4%
Northwest Volcanic Irish Potato Zone	21.7%	16.6%	-5.1%
East Congo-Nile Highland Subsistence Farming Zone	25.1%	24.5%	-0.6%
Central Plateau Cassava and Coffee Zone	19.5%	18.5%	-1.0%
Northern Highland Beans and Wheat Zone	31.9%	30.8%	-1.1%
Central-Northern Highland Irish Potato, Beans and Vegetable Zone	11.1%	16.5%	5.4%
Bugesera Cassava Zone	26.1%	9.7%	-16.4%
Eastern Plateau Mixed Agriculture Zone	12.1%	12.5%	0.4%
Southeastern Plateau Banana Zone	11.0%	17.0%	6.1%
Eastern Agropastoral Zone	12.3%	22.6%	10.3%
Eastern Semi-Arid Agropastoral Zone	15.7%	23.8%	8.2%

Food insecurity is variable between rural and urban households, with the urban area of Kigali being the least food insecure (WFP 2018). This is partly an outcome of the very high rates of income inequality in Rwanda. Food purchases are an important part of all Rwanda households provisioning strategies[25]. Poor households have less to spend on food than richer households, but the food purchases they make are a larger portion of the household budget. Moreover, a review of the food security and policy realms of Rwanda concluded that current policies have encouraged smallholders to increase their production of higher market value products (fruits and vegetables), to their micronutritional deficit. High value crops are produced for the market and cash incomes are used to purchase the caloric base of starches and carbohydrates to the detriment of eating a micronutrient rich diet (Weatherspoon et al. 2019).

Such micronutritional insufficiency impacts children strongly (Weatherspoon et al. 2019). Stunting statistics remain high for the country, as does the PoU. Nationally, the PoU is 36.8%, stunting in children under 5 is 36.9%, and prevalence of wasting in children under 5 is 2% (FAO et al. 2019). Households with livestock fared better on nutritional evaluations than non livestock owning households (Wetherspoon et al. 2019).

Key resources

Weatherspoon, D.D., Miller, S., Ngabitsinze, J.C. and Oehmke, J.F. *Stunting, food security, markets and food policy in Rwanda*. BMC Public Health BMC Public Health. 19. 10.1186/s12889-019-7208-0.

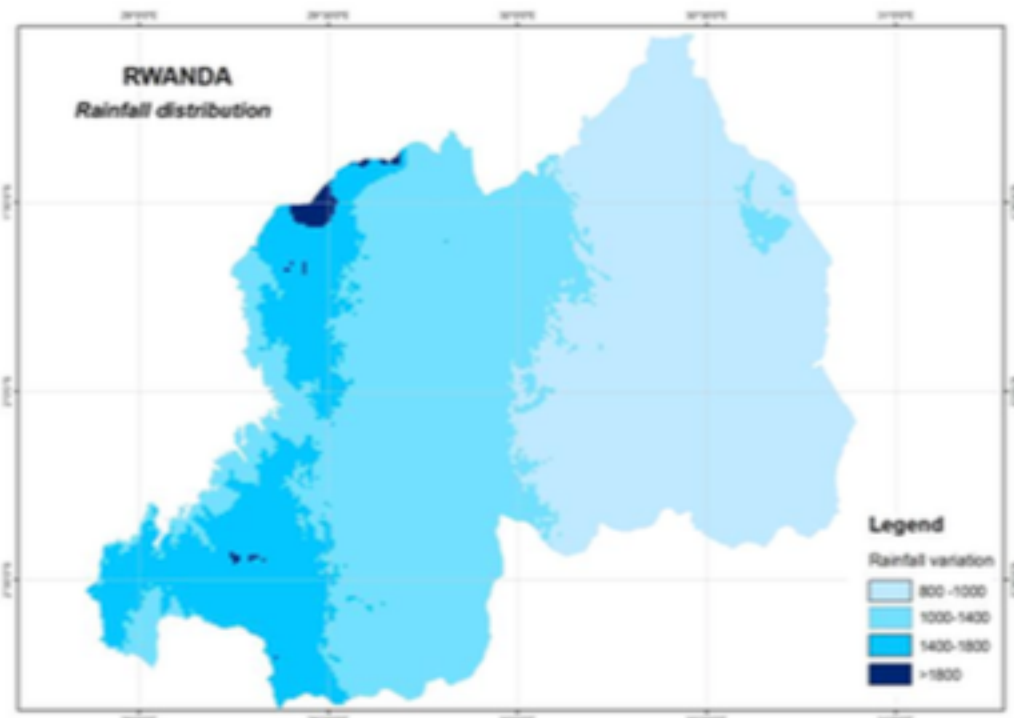
WFP. 2018. *Rwanda: comprehensive food security and vulnerability analysis 2018*. Data collected in March–April 2018.

[25] Despite a large portion of the population residing rurally and engaged in agricultural production, food purchases still fulfill a major portion of household diet. Rural production is predominantly rain fed small holders on landholdings of less than .59ha, a scale the FAO has determined to be too small to meet household dietary needs.

Climate change

Rwanda has a bimodal rainfall distribution across the entire country driven by the ITCZ, but regional rainfall varies in relation to the topographic variation (see Figure 31), with the western mountains historically receiving twice as much rain as the eastern plains. The western border of the country has weather that arises from Lake Kivu. Interannual variability exists through the vagaries of the ITCZ and effects of the El Niño Southern Oscillation.

Figure 31: Rainfall distribution for Rwanda (Kagera TAMP 2010)



A review of meteorological data found no significant trends in precipitation changes for the 1931–1990 period. Historic temperature data for Rwanda is limited to four weather stations, but from available 1971–2011 data, the review finds indications of rising temperature that matches global norms (McSweeney 2011). Another study of meteorological data concludes that the east to west climate zones have already shifted (Henninger 2013). Climate models predict further warming, with ranges between from 1°to 2.5°C, but the four reviewed models are very contradictory in regard to rainfall. One predicts significantly more rain, two predict little change and one predicts reductions (Tenge et al. 2013). Interannual rainfall variability is expected to increase, generating more difficulties in farmer decision making in regards planting times and varieties. Models do suggest that the rains that will occur will be more intense, heavy rains. Currently flooding events have already increased. High intensity rains also directly destroy crops and increase erosion on the many steep sided slopes used in agriculture. General warming will increase the production potential for some staple crops, but coffee and tea zones are predicted to decrease. Higher temperatures have implications for the eastern zones as increased evapotranspiration is predicted to make the eastern plains more vulnerable to drought conditions.

Key resources

McSweeney, R. 2011. *Rwanda's climate: observations and projections*. Smith School of Enterprise and the Environment, University of Oxford.
MoFAN (Ministry of Foreign Affairs of the Netherlands). 2018a. *Climate change profile: Rwanda*. The Hague: Netherlands.

Tenge, N. Mutabazi, A. and Thomas, T.S. 2013. Rwanda. In: Waithaka, M., Nelson, G.C., Thomas, T.S. and Kyotalimye, M. (eds), *East African agriculture and climate change: A comprehensive analysis*. Washington, D.C.: International Food Policy Research Institute (IFPRI): 247–277. (Available from http://www.ifpri.org/publication/rwanda) (Accessed 28 January 2020)

USAID. 2019. *Climate risk in Rwanda*. Country Risk Profile.

GHG emissions and livestock

Rwanda published its Second National Communication in 2012 utilizing years 2005 as its baseline. In the SNC Rwanda calculated a net negative GHG emission on the basis of a carbon sink, abandonment of managed lands, calculated at -9,000 Gg CO_2. The emission total was therefore -3534.6 Gg CO_2e (RoR 2012). IISD ran a further baseline projection for 2010 and concluded a 6,969 kt CO_2e without inclusion of the LULUCF. With LULUCF emissions for 2010 were calculated at 5,103 kt CO_2e (Stiebert 2013). In this period agriculture emitted 65% of non LLLUCF, with cultivated soils being the biggest contributor (Stiebert 2013). Rwanda published its Third National Communication in 2018 and updated its emission profile. Enteric fermentation and urea application are the major components of the calculated agriculture emission for 2015. The Land Use Category (FOLU) is still calculated to be a potential sink of carbon (RoR 2018). External data of Rwanda's GHG emissions calculated 7.59 Mt CO_2 e for year 2014, which is only 0.015% of the world total for that year (USAID 2018).[26] In this estimate the agricultural sector accounts for 39.5% of the emission. Contrary to the Stiebert (2013) calculation, the USAID reports that most of the agricultural emission comes from livestock-related activities, such as enteric fermentation (41%) and manure left on pastures (31%).

Key resources

RoR (Republic of Rwanda). 2018. *Third national communication: report to the United Nations Framework Convention on Climate Change*. Kigali, Rwanda: Republic of Rwanda.

Stiebert, S. 2013. *Republic of Rwanda: Greenhouse gas emissions baseline projection*. International Institute for Sustainable Development.

USAID. 2018. *Greenhouse gas emissions in Rwanda*. (Avaialble from https://www.climatelinks.org/resources/rwanda-greenhouse-gas-emissions-ghg-factsheet) (Accessed 28 January 2020)

[26] It should be noted that the Rwanda Fact Sheet (USAID 2018) has a numerical mistake in their representation of world emission percentage. It states Rwanda's emission was 7.59 Mt out of a world 48,892 Mt and presents this as 0.37% of world total.

Climate-smart livestock

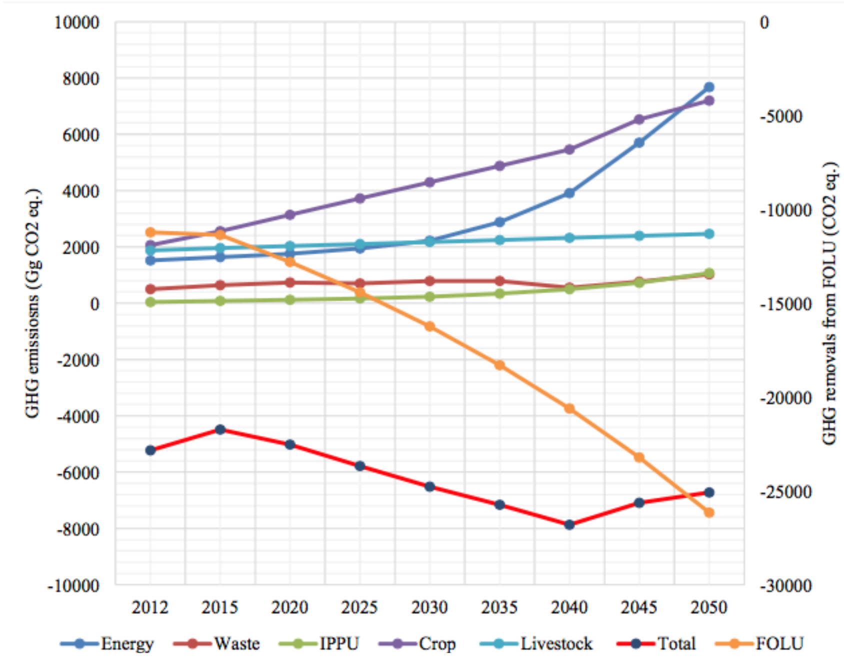
Rwanda has not adopted a specific CS framework in its policy planning but many of the key policy goals, such as a resilient and green economy, productivity and climate change adaptation for improved food security, and sustainable land management are CS adjacent. Recent Rwandan policies that set adaptation and mitigation goals include the 2011 Green Growth and Climate Resilience Strategy, the 2015 Intended Nationally Determined Contribution (INDC), the 2018 Third National Communication, and the 2019 National Environment and Climate Change Policy. (see World Bank and CIAT 2015 for a review of policies up to 2015 and how they relate to adaptation, mitigation and production). A World Bank review of CSA potential in African countries found that the policy environment and readiness to support public-private partnerships for development places Rwandan high on their index of CS amenability (called the Aggregated Policy Index) (World Bank 2018).

The Rwandan government has demonstrated its interest and institutional capacity for large scale agricultural reforms. Under the Vision 2020 a main goal was the modernization of crop and animal production. A particular program implemented was the Crop Intensification Program (CIP) aimed at increasing national productivity through rationalization of production based on land use zone designation and land consolidation. Productivity was to be increased through increased subsidized fertilizer use, access to improved seeds, and new post-harvest technologies. The CIP program focused on six priority crops: maize, wheat, rice, Irish potato, beans, and cassava. National productivity under this program did increase dramatically, three-fold for some crops.

The institutional will and capacity evidenced in the CIP success points to the potential positive impacts on adaptation, mitigation and environmental conditions that governmental priority actions will be able to have. Under the INDC the agriculture sector has two main actions: 1. Sustainable intensification of agriculture (with 6 sub sections) and 2. Agricultural diversity in local and export markets. The sustainable intensification of agriculture includes calls for agroecology linkages, interplanting techniques, nutrient recycling, water conservation, organic waste composting, organic fertilizer production and use, push-pull planting systems for pest management, terracing, and pursuit of reforestation and agroforestry techniques. Activity point 2 includes local biogas production for energy availability to allow for value addition processes to occur closer to the points of primary production and local market facilitation through infrastructure development (RoR 2015).

Many of these action points for adaptation and productivity laid out in the INDC are CSA approaches, even though they are not called CS in the governmental frameworks. Similarly, the government is addressing its mitigation needs through policy support to maintain and even increase the carbon sequestration potential of the land. This is pursued through land transformational practices that include reforestation and soil management planning. Under the mitigation plans in the Third National Communication the Land Use Category (FOLU) is calculated to be a potential sink of carbon through to 2050 (RoR 2018) (see figure 32). FOLU's ability to be a continued and growing CO_2 sink is based on aggressive governmental plans to support reforestation across the country including promoting mixed crop and tree agriculture through support for all farmlands to incorporate tree cover. Outside of the FOLU, emissions from all sectors are projected to rise but mitigation goals kept the gains modest.

Figure 32: Emissions under planned mitigation scenarios for Rwanda. Published in the Third National Communication (RoR 2018).



The National Environment and Climate Change Policy 2019 further establishes Rwanda's interest in pursuing green growth opportunities, and leveraging international interest in mitigation towards aid in reorienting its development planning towards climate resilience; it states:

> 'The environment and climate change represent an opportunity to catalyze realignment of Rwanda's development model to one that is climate resilient, based on lower GHG emissions, and takes full advantage of the green and circular economy. Climate finance flows and carbon asset mechanisms present an opportunity to access additional funding. This means accessing international financing for ambitious climate resilient and low emission development programs. For the private sector, this can entail developing financial and insurance services, engaging in projects to generate carbon credits for sale in international markets, exploiting new green economy opportunities and creating green jobs.' (MoE 2019)

This interest in mitigation and the green economy opens opportunities for climate-smart livestock approaches. The review of CSA in Rwanda identified zero grazing and improved pastures, utilizing climate smart grasses as the two main climate-smart approaches that could be applied. Biogas production was seen as viable especially when joined with the governmentally promoted zero grazing intensification (World Bank and CIAT 2015). Prasad et al. (2016) in their evaluation of the CSA potential of Rwanda propose a number of research and intervention goals but these are mainly crop focused. The direct livestock suggestion was for supporting increased integration of livestock and vegetable production. In a review of Feed the Future Projects in Rwanda, Henry et al. (2016) determined that many of the principles and approaches of CSA are already being incorporated into projects and suggests that future Feed the Future work should further implicitly incorporate CSA into its project development.

What is notable in the reviewed Feed the Future projects is the limited exploration of livestock systems. The only direct program on livestock was for Dairy Competitiveness. Similarly, the climate-smart approaches offered in the reviews mentioned above lack the diversity and specificity that are often addressed to crop based planning. This lack of climate-smart livestock diversity is important when considering the Livestock Master Plan which lays out a dairy, red meat, pork and chicken value chain development road map (Shapiro et al. 2017). This plan does not explore these productivity goals in relation to adaptation needs. As so much of livestock productivity currently happens in smallholder settings which are diverse around the country, careful context specific climate-smart livestock approaches should be considered for how to address the value chain productivity goals without compromising resilience of smallholders. Local resilience is not necessarily increased by national level productivity goals, as a review of a context specific application of the CIP productivity program points out. In a case study of CIP's on the ground application, the author found decreases in local adaptive capacity when the nationally imposed cropping and productivity goals were implemented (Huggins 2017). Similar care needs to be given to not allowing the third leg of CSA, mitigation, to dominate over adaptation, especially in light of potential project funding streams being tied to international GHG mitigation interests. Dairy intensification is already underway; reviews of the ways in which these productivity and mitigation programs are impacting adaption in context specific locations needs to be done.

Finally, as the livestock head count and trends analysis indicate other livestock herds beyond cattle will continue to grow. Climate-smart livestock opportunities for the existent swine, poultry and goat sectors should be pursued. Interest in reforestation creates opportunities for silvopasture projects. Apiculture is rarely addressed but should be evaluated for cultural appropriateness as bee keeping can fit into priority goals for environmental biodiversity and reforestation.

Key resources

Henry, K., Ngugi, M., Quinney, M. and Jarvis, A. 2016. *CCAFS Rwanda deep dive assessment of climate-smart agriculture (CSA) in USAID Feed the Future Portfolio in Rwanda*. Technical report.

Prasad, P.V., Hijmans, R.J., Pierzynski, G.M. and Middendorf, J.B. 2016. *Climate smart agriculture and sustainable intensification: assessment and priority setting for Rwanda*. Feed the Future Sustainable Intensification Innovation Lab.

World Bank and International Center for Tropical Agriculture (CIAT). 2015. *Climate-smart agriculture in Rwanda*. CSA Country Profiles for Africa, Asia and Latin America and the Caribbean Series. Washington D.C.: The World Bank Group.

Tanzania

Agricultural production and agroecological zones

Agroecological zonation done at the fine grade, like the original 1984 survey, evidences the range of variation in soil, climate and topography that exists across the large land mass of Tanzania (see Figure 33). However, a 10 zone agroecological map is more frequently referenced in URT publications (see Figure 34). Reference is also made to there being 49 agroecological zones that can be grouped into seven main zones (URT 2013b). The FEWSNET collaborative mapping process generated a highly detailed livelihood zone map and zone descriptions (see USAID 2018, and Figure 35). A condensed livelihood map was produced by Sokoine University of Agriculture and is being used in government planning (in use in the Agriculture Climate Resilience Plan URT 2014, see Figure 36). However, there does not seem to be a standardized map in use URT publications; the 2017 CSA Guideline utilizes both a different agroclimatic zone map from a 2006 project and the older agroecological zone map from 1984 rather than the ten zone condensed map.

Figure 33: Original agroecological zonation of Tanzania from (DePauw 1984). Image from URT (2017)

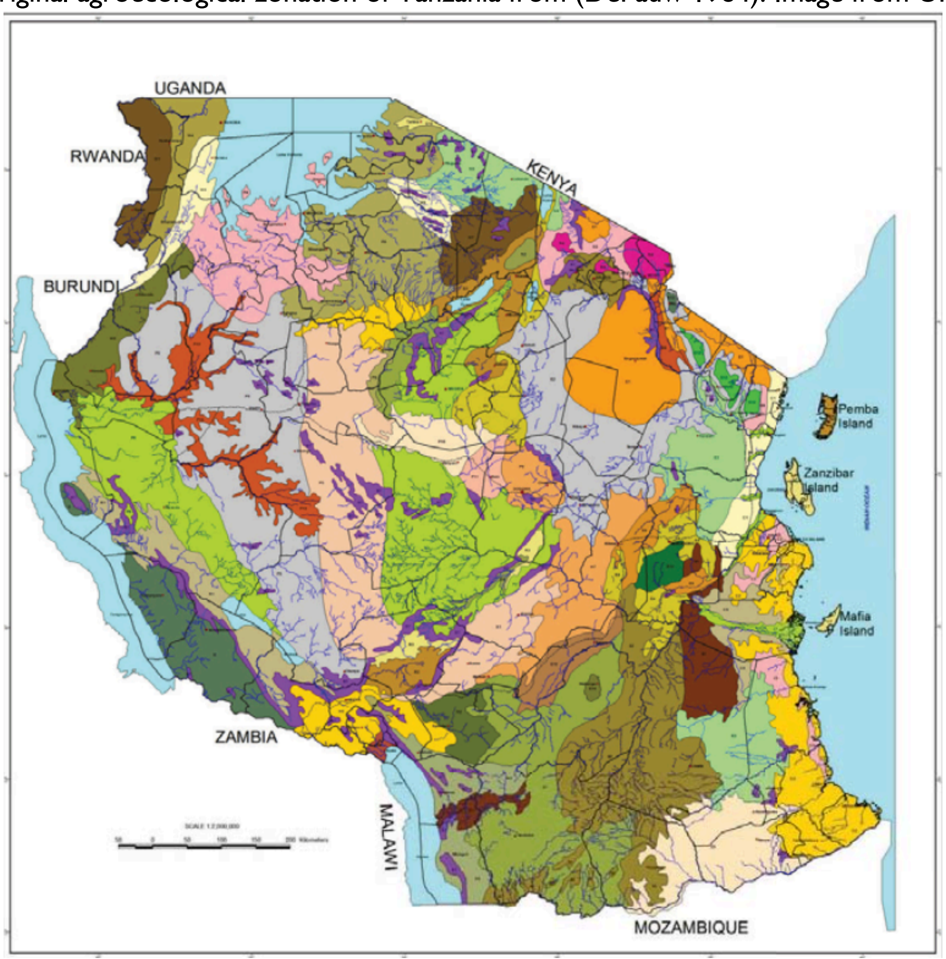


Figure 34: Simplified agroecological zonation, condensed to ten zones. Image from URT (2014)

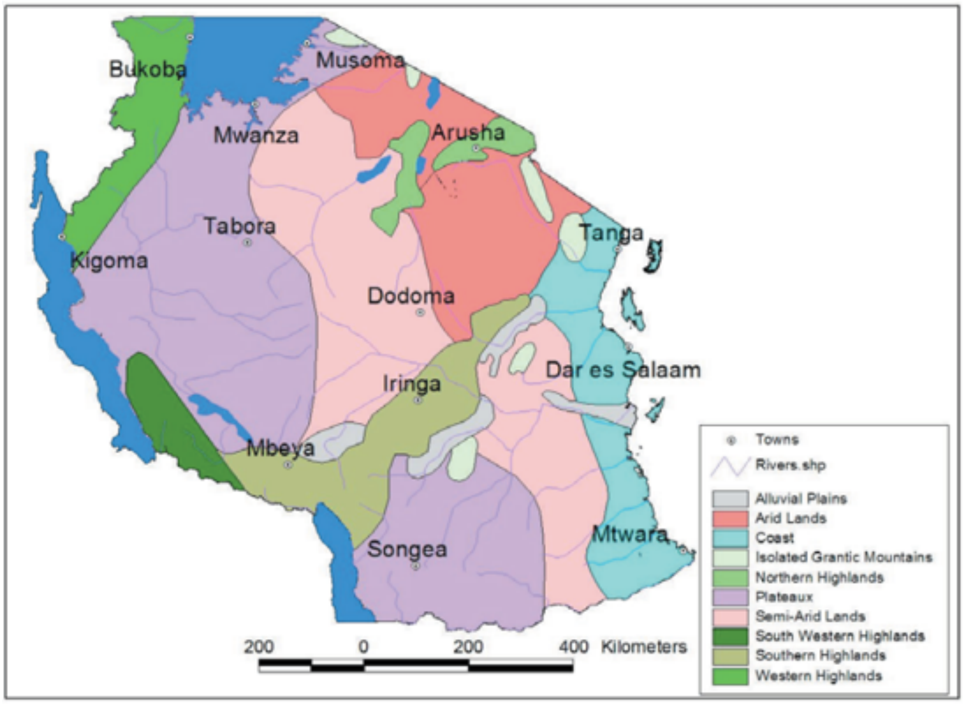


Figure 35: Livelihood map developed by FEWSNET and the Tanzanian Food Security Information Team. Map copied from USAID (2008)

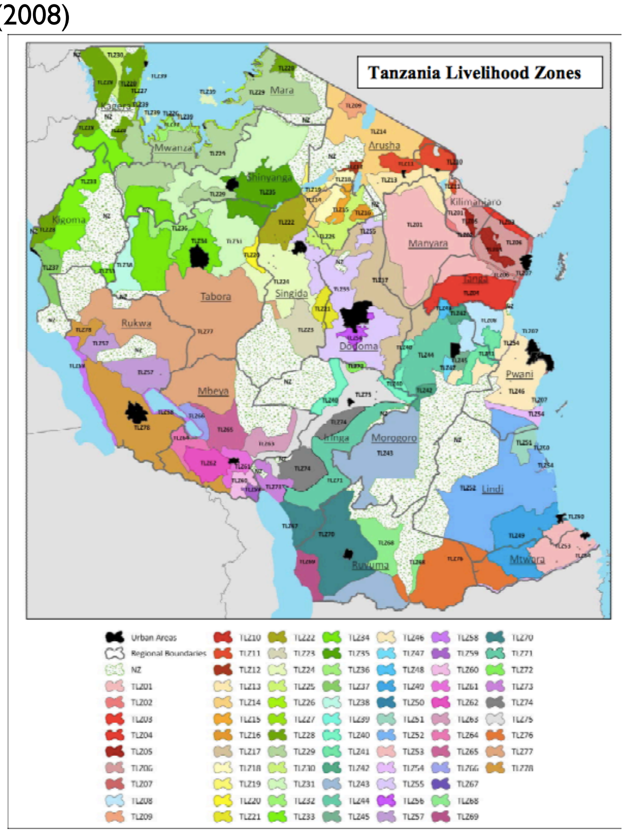
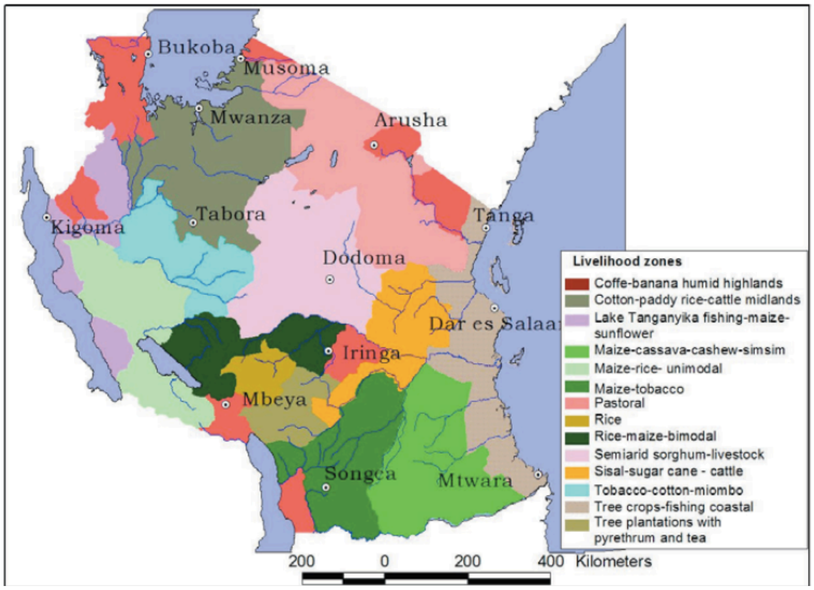


Figure 36: Condensed livelihood zone map (URT 2014)



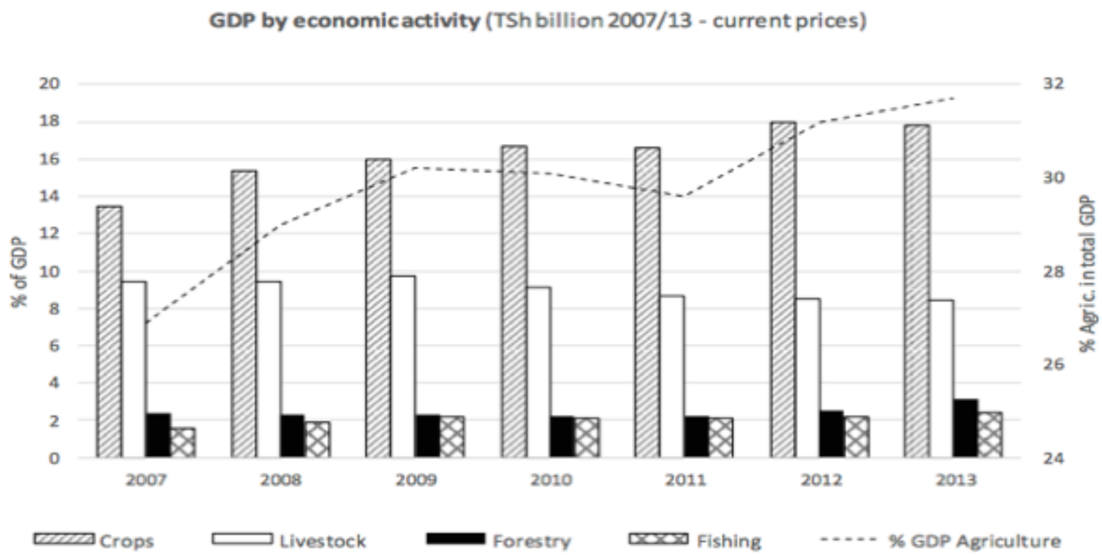
Statistics on labour and economy highlight how important agriculture is for the livelihood base of the nation. 68% of the Tanzanian work force is engaged in agriculture. The majority of holdings (83%) are smallholder producers (0.2–2 ha holdings) who in turn are responsible for almost 75% of the agricultural output (FAO 2018)[27]. When calculating from livelihoods rather than work force, the agricultural sector's primacy rises, as 80% of the livelihoods are considered to come from agriculture (WFP 2019), despite only 25% of the formal GDP arising from agriculture (URT 2017).

Of individuals involved in agriculture 55.8% are engaged in crop only enterprises, 41.8% in mixed, and only 2.4% are livestock only producers (data from 2016/2017 survey, published NBS 2018). Crop production is largely rain fed (country wide, only 2.5% of the production is irrigated, URT 2018a). (for crop production types by regions see URT 2018a as well as USAID 2008 for livelihood zones descriptions and dominate crops).

In the calculations of the formal economy, variations exist in refences to the value of the livestock sector versus crops; the 2016 Agricultural development plan lists livestock at ~8% of GDP, and crops at ~18% GDP (Figure 37). However, it is likely that these calculations undervalue livestock's contribution to the total economy. Such undervaluation has been found in worldwide reviews of livestock value (Moll 2005) as well in the ICPALD livestock re-valuations run in regional neighbour countries Kenya, Uganda and Ethiopia. One analysis of livestock value in Tanzania finds that the growth potential and value of the livestock sector has been underdeveloped in relation to the crop production (Engida et al. 2015).

[27] URT 2017 places 75% of the labor force in agriculture. WFP places 74% of rural population in agricultural practices.

Figure 37: Contributions of the subsectors to the total agricultural GDP. Chart from URT (2016), Agricultural Sector Development Programme Phase two.



Reviews of livestock production in Tanzania reference the four different production types (pastoralists, agropastoralists, mixed crop livestock and semi-intensive systems). Distribution of production types is related with agroecological zones. A simplified zonation map highlights the regional differences in production strategies (see Figure 38). Although 60%[28] of the national land is classified as rangeland, pure pastoralism is a very small portion of the national livelihood portfolio (only 2.4% agricultural operators are livestock only); agropastoral practices have increasingly been adopted by pastoral peoples. However, the national survey (URT 2018a) makes no distinction between agropastoral and mixed crop-livestock practices, rather it simply lists production as crop only, or mixed, or pure livestock. Such generalizations belie context specific cropping and livestock practices. Detailed livelihood data (see USAID 2008) highlights the different nature of livestock and types of cropping systems in the agropastoral vs mixed crop-livestock production practices. (see also Covarrubias et al. 2009 for a livestock and livelihood review).

[28] 60 % is referenced in URT 2014, some research papers list the figure 74% for rangelands

Figure 38: Simplified agroecological zone and livestock production practices. Notice how the arid pastoral regions runs through the country, and the highland production systems occur both in the north and the south. Figure and table from Nell et al. (2014).

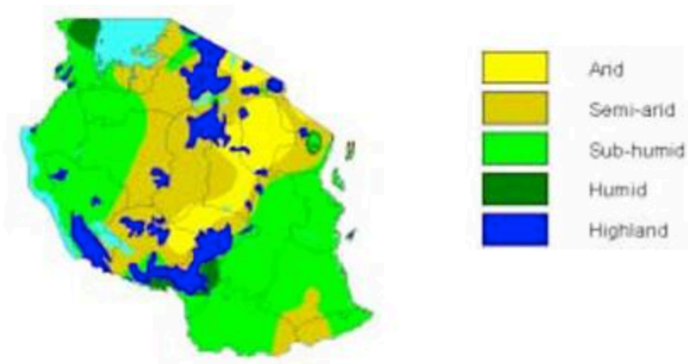


Figure1.1 Agro-ecological zones (FAO, AGAL, 2005)

Table 1.1 Agro ecological zones (based on Jahnke 1982 and the authors)

Agro-ecological zone	Description	Prevalent dairy system
Arid	Growing days below 90	Pastoralism
Semi-arid	Growing days from 90 – 179	Agro-pastoralism
Sub-humid	Growing days from 180 – 269	Small holder
Humid	Growing days 270 or more with high temperature and high relative humidity	Smallholder dairy
Highlands	Growing days 90 – 365; over 1500 m altitude, ranges from semi-arid to humid but average temperature below 20 C in the growing season	Smallholder dairy and medium and large scale dairy

The livestock herd of Tanzania is in the top herd sizes in all of Africa.[29] The 2015 livestock masterplan lists population numbers at: 25 million cattle; 16.7 million goats; 8 million sheep; 36 million poultry; and 2.4 million pigs. The recently released survey statistics for 2016/2017 increases the numbers for all except sheep: 30.67 million cattle; 19 million goats; 5.56 million sheep; 1.9 million pigs and 40.35 million chickens and other animals (URT 2018a). These herd numbers include both the mainland and the islands of Zanzibar (see Table 12). The URT numbers show the importance of chickens across all of Tanzania and highlight that smaller livestock production of ducks and even guinea pigs are taking place. (see the URT 2018a for details on regional distributions of cows, goats, sheep, pigs and chickens).

[29] Sometimes referenced as being the second largest, sometimes the third. Ethiopia and Sudan are the other top herds.

Table 12: Livestock population numbers for Tanzania in total and disaggregated between the mainland and Zanzibar. Note the relative importance of chickens and ducks to Zanzibar, compared to goat and cattle. Table constructed from data in URT 2018a, reporting the statistics from the 2016/2017 agricultural survey.

	Total	Mainland	Zanzibar
Cattle	30,672,001	30,496,687	175,314
Goat	19,055,651	18,947,657	107,993
Sheep	5,565,986	5,565,468	517
Pig	1,952,801	1,952,801	0
Indigenous chicken	40,349,893	38,595,106	1,754,786
Donkey	547,081	546,996	85
Ducks	1,934,131	1,832,064	102,066
Guinea pigs	565,278	564,894	385
Turkey	219,225	216,931	2,294
Rabbits	158,579	150,681	7,898
Dogs	2,415,695	2,408,129	7,567

The smallholder producers that dominate the agricultural sector are often more integrated into local, or informal market systems than into formal production chains (FAO 2018). This was found to be particularly true of the dairy sector. This in turn has implications for development, intensification and food safety policies (Nell et al. 2014). In their review of the dairy sector they point to the need to consider the formal and informal market chains that already exist, rather than only focusing on formal or registered production; expansion and support of the informal sector should be considered in policies as well as support for the licensed sector (Nell et al. 2014). Governmental interest in licensing can be seen in its inclusion of the question about registration in the 2016/2017 survey. Strikingly, only 18% of farms were registered. The need to pay attention to the policy environment in which livestock practices are occurring and developing is highlighted in Halloran and Magid's (2013) analysis of the challenges of urban agriculture and livestock in the rapidly expanding urban and peri-urban areas of Dar es Salaam. National agricultural policies have had a de facto assumption that agriculture is rural; individuals operating in the peri-urban and urban area are often in tenuous relations with licensing, land rights and integration into formal markets. Urban and peri-urban producers have to balance choices of expansion and investment against their tenuous land and regulatory rights (Halloran and Magid 2013).

Overall developmental interest has been focused on the dairy sector, as it is wide spread in the landscape, important in food and nutrition, underproductive, and under integrated into formal markets and seen as having high potential for mitigation investment (reviews of the dairy value chain include Dillman and Ijumba 2011; Njombe et al. 2011; Häsler et al. 2014; Ogutu et al. 2014; Nell et al. 2014; FAO and NZAGGRC 2019) Alongside the dairy value chain the 2015 Livestock Master Plan targets the poultry, red meat, and pork value chains as priority sectors for development pushes through supportive policies and private-public funding initiatives (see Michael et al. 2018 for the Livestock Master Plan; see URT 2015 for the Livestock Modernization Initiative; see also Ringo and Mwenda 2018 for a review of the Poultry sector).

Key resources

URT (United Republic of Tanzania). 2018a. *2016/2017 annual agriculture sample survey: crop and livestock report*. (Available from https://www.nbs.go.tz/index.php/en/census-surveys/agriculture-statistics/57-2016-17-annual-agriculture-sample-survey-crop-and-livestock-final-report) (Accessed 24 January 2020)

URT (United Republic of Tanzania). 2016b. *Agricultural sector development programme phase two*. Dar es Salaam, Tanzania: URT.

Michael, S., Mbwambo, N., Mruttu, H., Dotto, M., Ndomba, C. et al. 2018. *Tanzania Livestock Master Plan (2017/2018 – 2021/2022)*. Nairobi, Kenya. ILRI. https://hdl.handle.net/10568/100522

Food and nutrition security

Tanzania is mainly a food secure nation, though regional variation in vulnerability exists (see figure 39, and 40). The nation is considered to be self-sufficient in its food production (URT 2017), but upward of 45% of the rural population can be food insecure (Haug and Hella 2013; World Bank 2012). 70% of the population are rural smallholders depending on rain fed production as the main livelihood strategy. Lean food seasons are experienced by many of the population, and vulnerability to food insecurity can be from production failures or price shocks. Because of the general level of national food self-sufficiency, what food insecurity that is felt in the country arises more from internal events relating to production, distribution and national food pricing policies than from external commodity markets; the Tanzanian food sector is only modestly affected by international food prices (Kiratu et al. 2011). Tanzania has had transformative urbanization since the mid 20th century, and in the last 24-year period from 1988 to 2012, the urban population in Tanzania has gone from 17.8% to 29.1% (Wenban-Smith et al. 2016). Tanzania has a history of policy support that prioritizes food availability and costs to the urban consumers, which at times can have negative implications for the livelihoods, and thus the food security, of rural producers (Haug and Hella 2013).

Tanzania has had rapid economic growth (referenced as 7%[30]) over the last years, but development gains against poverty are more in the urban areas. Poverty levels (measured at income less than two US dollars a day) are still high, and 80% of those in poverty are rural households. Despite these economic gains measures of undernourishment remain high for a country with such food production capabilities. For the years 2016–2018 prevalence of under nourishment for the nation was at 30.7, prevalence of stunting for children under 5 was 34.5%, and for wasting it was 4.5% (FAO et al. 2019). In their review of food security Haug and Hella (2013) conclude 'the main finding is that the Tanzanian Government is struggling with the difficulty of addressing the twin goals of balancing national food availability with affordable food prices for urban and rural consumers.'

[30] The Tanzanian Bureau of Statistics reported GDP growth of 7.0% for 2018. However, this high rate is questioned by outside review. See: https://www.reuters.com/article/us-tanzania-gdp/tanzanias-economic-growth-slows-in-first-quarter-as-construction-softens-idUSKCN1UN07F

Figure 39: Figure Regional food insecurity vulnerability. Image from URT (2014). Data credited to MAFC (2011/2012)

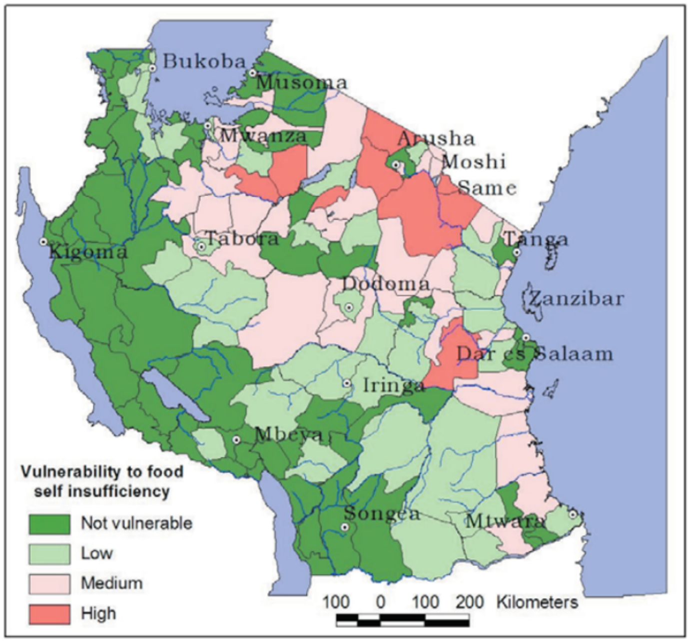
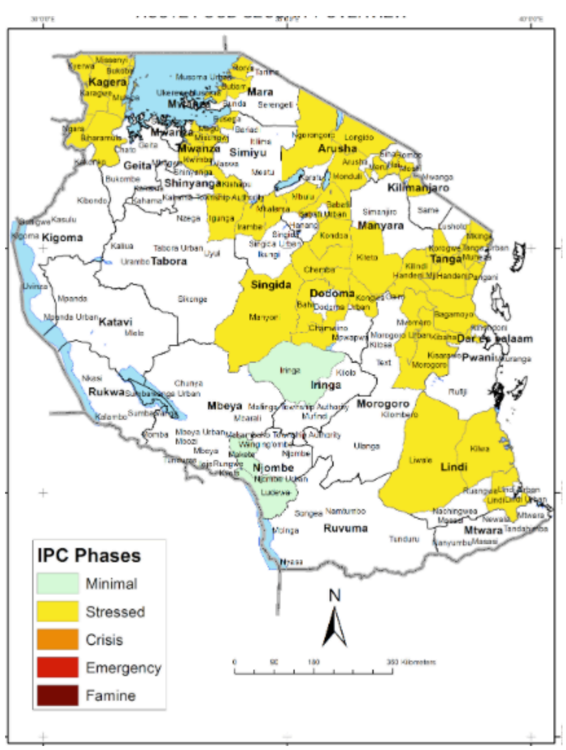


Figure 40: The food insecurity map developed from the 2017 national comprehensive food security and nutrition assessment report (URT 2017). This report notes that the overall 2016/2017 rains were normal, there had been some crop production decreases, but national production was deemed to still be in a positive self-sufficiency value. Thus, the stressed regions are more from chronic food insecurity rather than an acute event.



Key resources

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WFP (World Food Programme). 2012. *Comprehensive food security and vulnerability analysis.* Tanzania: WFP.

URT (United Republic of Tanzania). 2017a. *Comprehensive food security and nutrition assessment report.* Tanzania Food Security and Nutrition Analysis System – MUCHALI.

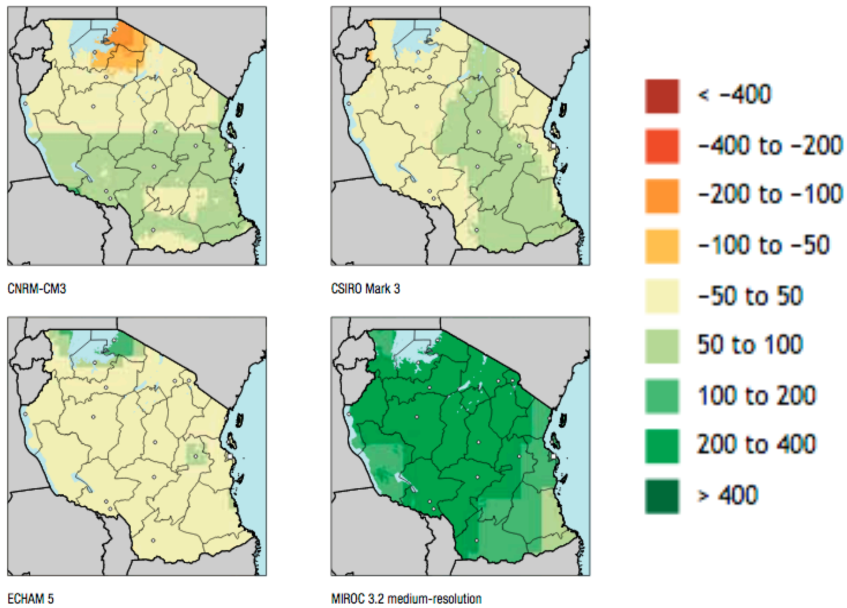
Climate change

Tanzania has two different weather patterns. The north eastern highlands, Lake Victoria basin, and northern coast have a bimodal rainfall pattern which is driven by the ITCZ. Rains historically were the *vuli* rains from August /September to December/January, and the *masika* rains from March to May/June. The rest of the country is unimodal with a generalized rainier period starting in November/December and continuing through to mid-April.

In an analysis of historic temperature and precipitation data for the period 1961–2015 from 18 meteorological stations shows a significant increasing trend for both the maximum and minimum temperatures. The number of hot nights has increased more than the number of hot days. (Chang'a et al. 2017). There has also already been a 1.0°C rise in mean annual temperatures (McSweeney et al. 2012). Rainfall has had statistically significant decreases, but there is no statistical trend in the proportion of rain occurring in heavy events (McSweeney et al. 2012).

Climate models for Tanzania vary markedly in their predictions of rainfall increases or decreases. Under the CNRM-CM3 model the basin area near Lake Victoria will be drier, but in the ECHAM 5, that area is the main area predicted to have rainfall increases. The CSIRO Mark 3 shows mild increases on a north south band, while the CNRM-CM3 place a wetter band across the southern portion of the country. The MIROC is predicts a general wetter trend for the whole country (Kilembe et al. 2013) (see Figure 41). In another review of models though, the conclusion is that the projections 'are broadly consistent in indicating increases in annual rainfall' with projections of increases in the wet season of all parts of the country (McSweeney et al. 2012). Temperatures are modelled to increase by 1.0 to 2.7°C by the 2060s (McSweeney et al. 2012), or in a range of 0.5 to 2.1°C (Kilembe et al. 2013).

Figure 41: Four downscaled general circulation models showing change in mean annual precipitation up to 2050. Image from Kilembe et al. (2013), who credit the data to Jones, Thornton and Heinke (2009).



Modelling of potential crop impacts of these rainfall and temperature changes point to arable land patterns will shift, with some crops, cassava, sorghum, banana and rice increasing in cultivation area. However, despite gains in arable land, yields are predicted to decrease for many crops (see Kilembe et al. 2013 for mapped crop yields by model prediction, see CIAT, World Bank 2017 for infographics on yield trends for the major crops and for chicken and cattle). General climate change risks for livestock production include increased spreads of pests and diseases, water availability, heat stress and forage lose. Arndt et al. (2012) modelled crop yields for 110 districts in the country under four models and concluded 'relative to a no climate change baseline and considering domestic agricultural production as the principal channel of impact, food security in Tanzania appears likely to deteriorate as a consequence of climate change.' (See Kahimba et al. 2015 for a review of literature on crop production, climate change and food security)

Key resources

Kilembe, C., Thomas, T.S., Waithaka, M., Kyotalimye, M. and Tumbo, S. 2013. Tanzania. In: Waithaka, M. Nelson, G.C., Thomas, T.S. and Kyotalimye, M. (eds), *East African agriculture and climate change: A comprehensive analysis*. Washington, D.C.: International Food Policy Research Institute (IFPRI): 313–345.

McSweeney, C., New, M. and Lizcano, G. 2012. *UNDP climate change country profiles: Tanzania.* (Available from https://www.geog.ox.ac.uk/research/climate/projects/undp-cp/index.html?country=Tanzania&d1=Reports) (Accessed 28 January 2020)

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URT (United Republic of Tanzania). 2014a. *Agriculture climate resilience plan, 2014–2019*. Dar es Salaam, Tanzania: URT.

GHG emissions and livestock

Tanzania filed its Initial Communication to the UN in 2003 and filed its Second National Communication in 2014. In the SNC, Tanzania calculated a GHG emissions report for base year 2000. It reported that the agriculture, land use change and forestry (AFOLU) sector was the biggest emissions sector. Field residue burning was the largest subsector for agriculture.
The total GHG emission from all sectors in Tanzania is reported to be 286.49 Mt CO_2e; comprised of 72.7% (208.04 Mt CO_2e) from land use change and forestry, 17.3% (49.7 Mt CO_2e) from agriculture, 7.8% from energy, 1.6% from waste and .5% industrial processes (USAID 2018b). Forest land loss and biomass burning are the main emitters. One government report lists emissions by sector as 48% burning biomass, 18% enteric fermentation and 13% other (URT 2017b).

Key resources

URT (United Republic of Tanzania). 2014b. *Second national communication under the United Nations framework convention on climate change (UNFCCC)*. Dar es Salaam, Tanzania: URT.

USAID. 2018. *Greenhouse gas emissions in Tanzania*. Factsheet. (Available from https://www.climatelinks.org/resources/tanzania-ghg-emissions-factsheet) (Accessed 24 January 2020)

Climate-smart livestock

The policy environment for developing and deploying climate-smart livestock approaches in Tanzania is supportive but complex. The development of the Tanzanian CSA approach, published in 2017 as the Climate Smart Agriculture Guideline, is situated in the parallel tracks of general agriculture policy and the climate change communications and policies. Tanzanian government vaguely ignored rural agricultural or implemented polices through the lens of supporting food access and food security of urban population sometimes to the detriment of the rural producers (Haug and Hella 2013). However, in the 2000s, policies and strategies have been shifting toward recognizing the importance of directly supporting agriculture and agricultural producers. At the end of 2009 the government launched *Kilimo Kwanza* (Agriculture First) as a national resolution to recognize the prime importance of agriculture in Tanzania and put agricultural planning at the center of development and policy agendas. Under this reorientation Agricultural Sector transformation and modernization become the path forward for achieving the Vision 2025. Under this vision the main barriers to the agricultural sector are: lack of access to, and use of improved seeds; lack of investment in, and adoption of, mechanization and productivity increasing technologies; lack of financing; rainfall variability and low adoption of irrigation where that is possible. In 2010 the Livestock Sector Development Strategy was launched, to be followed in 2015 by the Tanzania Livestock Modernization Initiative pulling together older livestock development and funding streams toward addressing the role of the livestock sector in Tanzanian progress toward its Vision 2025.

At the same time that development and modernization of the agricultural sector was being promoted, Tanzania was also having an array of climate change and resilience policy statements and programmatic initiatives. Each of the national communications under the UNFCCC (2003 Initial Communication, 2007 NAPA, 2014 Second Communication, and 2018 INDC) have some elements of adaptation or mitigation planning and many government policies set the institutional frameworks in which these adaptation and mitigation goals will be implemented. (See Majula et al. 2014 and 2015 for comprehensive reviews of URT policies and initiatives that intersect adaptation and mitigation planning).

The most recent national communication (the INDC, URT 2018b) sets the national ideal of 'climate resilient development pathways.' For the livestock sector this includes: a) Promoting climate change resilient traditional and modern knowledge on sustainable pasture and range management systems; b) Enhancing development of livestock infrastructures and services; c) Promoting livelihood diversification of livestock keepers; d) Promoting development of livestock insurance strategies (URT 2018b). These livestock goals are alongside general agricultural sector goals of improved land and water management, increasing research, knowledge extension, crop insurance and increasing yields through CSA[31]. For mitigation the INDC 2018 target sectors are forestry, waste, transportation and energy. For forestry the goals are conservation, tree planting and agroforestry supportive policies. Mitigation efforts in the waste sector are: landfill management, waste to energy technologies and promoting co-generation[32] (URT 2018b).

Other climate change strategies and plans exist: the 2012 National Climate Change Strategy; the 2014 Agriculture Climate Resilience Plan; and the 2017 Climate-Smart Agriculture Guideline. Despite climate smart only being referenced in the INDC as a tool for increasing yields, Tanzania has in fact embraced a wide range of CS techniques and has been the site of many CS applications and research projects. (see for example: Ogada et al. 2018 on Climate Smart Villages, a testing of facts that influence adoption rates of climate-smart approaches; Mandera et al. 2019 on the value of participatory approaches in assessing the resilience and productivity capacities of climate-smart approaches; Kimaro et al. 2019 on the CS value of agroforestry techniques; Mwongera et al. 2017 on usefulness and possibilities of a rapid rural appraisal approach for selection of potential CSA approaches within context specific locations; and Nyasimi et al. 2017 for a quantitative analysis of the factors that influence adoption of climate-smart approaches). Comprehensive overviews of CSA programs and approaches in Tanzania can be found in the CIAT, World Bank 2017 CSA Country Profile as well as in the FANRPAN 2016 CSA Tanzania Case Report (Both of these offer helpful overviews of the policy environment for CSA enactment in the country, see also Rioux 2017 for another overview and guidelines for CSA in Tanzania).

The CSA Country Profile suggests the top livestock climate-smart approaches for the country: for poultry, semi intensive production, improved breeds and free range systems; for cattle, traditional in situ fodder conservation, pasture management, local water/borehole improvements; and includes fish systems, aquaculture-agriculture, or aquaculture-livestock mixes and cage cultured fish. The FANRPAN review also gives an excellent overview of CS types that can or have been attempted in Tanzania. It is striking in their list that they include reference to peri-urban pig keeping systems, as for so much of the CS literature if it tackles livestock it is cattle, occasionally poultry or fish, and even less frequently

[31] Exact wording of the agriculture sector adaptation goals is a) Up-scaling the level of improvement of agricultural land and water management; b) Increasing yields through inter alia climate smart agriculture; c) Protecting smallholder farmers against climate related shocks, including through crop insurance; d) Strengthening the capacity of Agricultural research institutions to conduct basic and applied research; e) Strengthening knowledge, extension services and agricultural infrastructures to target climate actions.

[32] For the Transport sector goals are: low emissions transport and mass transport; for the energy sector: energy diversification, clean technologies, natural gas for cooking and rural electrification (URT 2018).

reviews of small ruminant systems. This report also notes that destocking of cattle in favour of small ruminants is being seen in pastoralist communities and that this should be considered the CS choice, despite the existing governmental goal of general destocking of pastoralism, not diversification (FANRPAN 2016).

The URT CSA guidelines propose a set of climate-smart livestock practices to be pursued for the country. These are: improved livestock breeds; adapted livestock; improved feeding (which includes traditional in-situ fodder conservation, *Ngitili* practices, *Olelii* practices, alternative water sources for livestock, zero grazing, pasture management); manure management; and on farm biogas production. These are only broadly defined, and aside from the traditional fodder conservation methods they lack context or regional specificity. What is lacking in Tanzania CSA (as in most countries CSA reviews) is detailed, context specific options and research on livestock cases. Rosenstock et al.'s (2019b) systematic review of mitigation and adaptation studies in south and East Africa highlights the need for this type of climate-smart research. Of the 150 production system projects that fit their systematic review criteria, only 3% were about meat production, and less than that about milk. In fact, 80% of the climate-smart style studies addressed cereal crop production (Rosenstock et al. 2019b).

One study in Tanzania shows that livestock climate-smart approaches are amenable to detailed quantified review. Shikuku et al. (2016) have modelled the CSA outcomes of productivity and mitigation in a location specific test of the variables of improved breeds, improved feeding (quality) and improved feeding (quantity). Utilizing local knowledge and data to generate possible and plausible feeding regimes and likely breeds of cattle in the region, the researchers modelled the productivity outputs versus the likely emissions rates for these scenarios. Their results point to the general conclusion that improved feeding helps with productivity even without improved breeds, but the productivity outcomes are better when feed improvements are given to improved breeds; however, at the same time these improved breed's productivity is more sensitive to variation in the food quantity. What is unique about this modelling scenario is that it works from the context specific fodder and forage availability, rather than idealized feed regimes which would not be tenable for some of the rural areas. This study by Shikuku et al. (2016) demonstrates the possibilities of detailed work in livestock system climate-smart approaches.

The URT CSA guideline lays out a few broad livestock activates. What is now needed is for these broad CSA activities to be planned for and operationalized through reference to the detailed actions and goals of the Tanzanian Livestock Modernization Initiative (URT 2015) and the newer 2018 Tanzania Livestock Master Plan. Opportunities exist for the development and deployment of climate-smart livestock approaches under these value chain plans. A list of potential climate-smart approaches includes: semi-intensive (free-range combined with intensive systems) chicken production; improving breeds through crossing indigenous breeds resistant to diseases with high yielding breeds; breeding for heat stress tolerance; forage and fodder production; traditional in situ fodder conservation for cattle; improving range management for livestock production; enhancing biological control of tsetse fly; promote indigenous knowledge; livestock diversification and small ruminant adoption; animal health support measures including veterinary services and AI, information services and financial service provision like index based livestock insurance. Moreover, the mixed crop-livestock systems that dominate in Tanzania give lots of space for climate-smart approaches that deal with the mixed systems; manure management, crop residue management, intercropping for fodder production, silvopasture, beekeeping and biogas production.

Key resources

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Annex II: References and resources

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