Current situation and plausible future scenarios for livestock management systems under climate change in Africa

Working Paper No. 307

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

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Abstract

The aim of this study is to review the literature and provide a technical brief to the African Group of Negotiators Experts Support (AGNES) on the effect of climate change on livestock across the continent up to 2050, highlighting the adaptation needs and options. The report provides a brief description of: (i) the different livestock farming classification systems; (ii) the key challenges and impact of climate change on livestock and the farming systems; (iii) the likely future trends and scenarios; (iv) the top adaptation actions that can be taken and (v) their enablers and barriers to uptake. The report also addresses adaptation co-benefits, gender and youth, and traditional knowledge and institutions. It looks at knowledge gaps and how global trends may influence the livestock industry in Africa.

There is evidence that land surface temperatures are rising faster across Africa than in any other continent and that climate variability is increasing. The report emphasizes that coping with climate variability is as big a challenge as coping with climate change. It is agreed that there is considerable variation in the projections between different models, and it is difficult to accurately or confidently project exactly what the future holds. The challenges identified include: (i) the decline in quality and quantity of animal feeds and forage; (ii) a reduction in water availability; (iii) heat stress; (iv) biodiversity change; (v) changes in the distribution and occurrence of livestock pests and diseases; and (vi) increased livelihood and income vulnerability affecting food security, purchasing power and resilience.

Potential adaptation responses include: (i) migration of both people and livestock, including urbanization and education of the population; (ii) improving water conservation; (iii) increasing intensification and shifting to mixed crop-livestock farming; (iv) pasture reseeding and conservation; (v) improving early warning, risk management and the use of technology; (vi) diversification both within livestock keeping with cross-breeding or changing herd species composition, and diversification out of livestock and agriculture into other livelihoods; and (vii) improved hygiene and quarantines to combat disease threats.

Activities and interventions providing adaptation co-benefits are: (i) climate smart and conservation agriculture; (ii) improved natural resource and sustainable rangeland management; (iii) biodiversity and ecosystem services; (iv) agroecology; (v) sustainable intensification; (vi) reducing methane emissions; (vii) policy change and enabling environments; and (viii) market opportunities and diversification. National priorities and local contexts must guide any response planning.

Keywords

Livestock; climate change; Africa; adaptation.

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Contents

1. Introduction and overview of climate change trends and impacts in Africa

1.1 Aim and purpose

This paper reviews and analyses climate change related livestock issues in Africa, concentrating on the adaptation aspects required with additional attention to co-benefits resulting in mitigation. The main aim of the paper is to provide technical information in support of the African Group of Negotiators Experts Support (AGNES) in its preparation of the common African position for submission on the Koronivia Joint Work on Agriculture (KJWA) topic 2e, "Improved Livestock Management Systems, including Agropastoral Production Systems and Others". It is widely agreed that, to date, there has been relatively little research or evidence on the impact of climate change on livestock production globally let alone in Africa (Rojas-Downing et al. 2017). This paper therefore pulls together the available literature on the topic, including peer-reviewed journal articles, grey literature and International Panel on Climate Change (IPCC) reports, particularly the Special Report on Climate Change and Land (SRCCL) to synthesize available findings and highlight the knowledge available to inform the African Group of Negotiators (AGN) in formulating a common position on the topic for submission to UNFCCC.

1.2 Background

Regions or countries with low per capita GDP levels are generally more at risk from the impacts of climate change, firstly because they may be poor since they already have "climates that are close to physical thresholds" and secondly because they are often more heavily dependent on natural capital, outdoor work such as agriculture and farming, and thirdly are poorer and have less financial capacity to adapt quickly (Woetzel et al. 2020). Thirty-three out of the world's forty-seven Less Developed Countries (LDCs) are in Africa (Langlois 2017). Sixty percent of Africa's land surface is classified as drylands with low and very variable annual rainfall and high temperatures where evapotranspiration is greater than precipitation, resulting in pastoralism or agro-pastoralism, with or without mobility, being the most appropriate land use practice and therefore main livelihood for 270 million people and the majority of livestock in Africa (Koohafkan and Stewart 2008). For millennia, mobility has been a key component of livestock keeping across most of Africa, except in parts where there was permanent water or climate is suitable for cultivation where mixed crop-livestock farming took place. Only in recent times has there been a shift to intensification and settlement, and mobility has become more difficult for a number of reasons including fragmentation of rangelands due to competing land use claims, fencing of agricultural lands, and in some cases conflict. Two of the main current drivers of change in livestock keeping in Africa’s drylands are access to rangelands and access to markets, and these are associated with various enablers or blockers such as population growth and human demographics, governance, drought and climate change (Catley et al. 2012). Given the many changes underway in Africa and globally, the futures of livestock keeping and pastoralism in Africa are many (Herrero et al. 2014).

1.3 Why livestock?

This paper concentrates on livestock because livestock not only contribute significantly to climate change and greenhouse gas (GHG) emissions at the global level, but also because livestock production contributes significantly to the economies of many African countries. The livestock sector contributes about 30-50% of agricultural GDP and supports the food security and livelihoods for about one-third of the population, or about 350 million people (AU-IBAR 2016). In addition to food security and income, livestock in Africa also are important for the draft power, they provide the manure for fuel and fertilizer and their cultural importance (Thornton and Herrero 2010).

Given the great importance of livestock within Africa, it is important to assess the impacts climate change may have on the sector. Some livestock systems in Africa may be able to adapt to climate change by virtue of their management approaches (e.g. mobility and high percentage of herds with indigenous breeds) and the wide range of agro-ecological zones and the socio-ecological systems that they cover. The great majority of ruminants (at least 70% of the cattle, sheep and goats; Herrero et al. 2017) in Africa are reared and are dependent on grazing natural pasture as the main component of their diet. There are also large numbers reared in a mixed farming system, where crop residues and grains, food leftovers or weeds from the farm are also important in the diet. Thus, the impact of climate change on crops will also be significant to livestock, especially since mixed farming is one adaptation response that is currently receiving some attention and promotion as an adaptive mechanism in some African production systems, although they may be management-intensive and have higher labour requirements in some circumstances.

Many of the proposed adaptation interventions and recommendations may have negative impacts on resilience, mitigation or production parameters, and there are no simple silver-bullet solutions.

The dynamics of livestock and climate change within the diverse systems of Africa need to be fully understood in the global picture and with regards to its own peculiarities and uniqueness.

1.4 Setting the scene: Key issues and starting points

Woetzel et al. (2020, p. viii) report that climate change will have direct effects on "five socioeconomic systems: liveability and workability, food systems, physical assets, infrastructure services, and natural capital". All of the above five systems will affect livestock management and in turn will be affected by livestock management. African livestock systems are multi-faceted, and climate change interventions have to be considered in conjunction with their impacts in terms of economic security, food and nutrition security, livelihood vulnerability and sustainable alternative options, cultural identity and norms, population growth, demographics and job creation. In Africa, livestock are not just an agricultural component, but also a form of insurance against drought (Kazianga and Udry 2006). Diversification into animals (including within different breeds and species of animals) or plant crops has long been a coping or adaptation strategy of African farmers.

Importantly, especially in sub-Saharan Africa, it is not just temperature and rainfall that are climate change issues, but the high variability in rainfall creates problems for farmers (Sultan and Gaetani 2016); this non-equilibrium environment severely restricts agricultural diversification and opportunity in large parts of Africa (Waha et al. 2018). It is also the reason that mobility is so necessary in the dryland systems where animals have to move to find vegetation. When this mobility is restricted, unsustainable grazing patterns can emerge resulting in degradation.

There are substantial regional differences in the projections of the nature and extent of likely future changes in climate. Increases in average temperature over land in Africa are larger than the global average and are not uniform over all of Africa. Rainfall pattern changes are more uncertain than temperature changes, while rainfall has become more intense and there is increasing variability in the start and end of rainfall seasons. Floods, droughts and other extreme events are likely to become more common in the future. Some parts of Africa, particularly east Africa, are projected to become somewhat wetter, whilst in others a drying effect is projected (west and southern Africa).

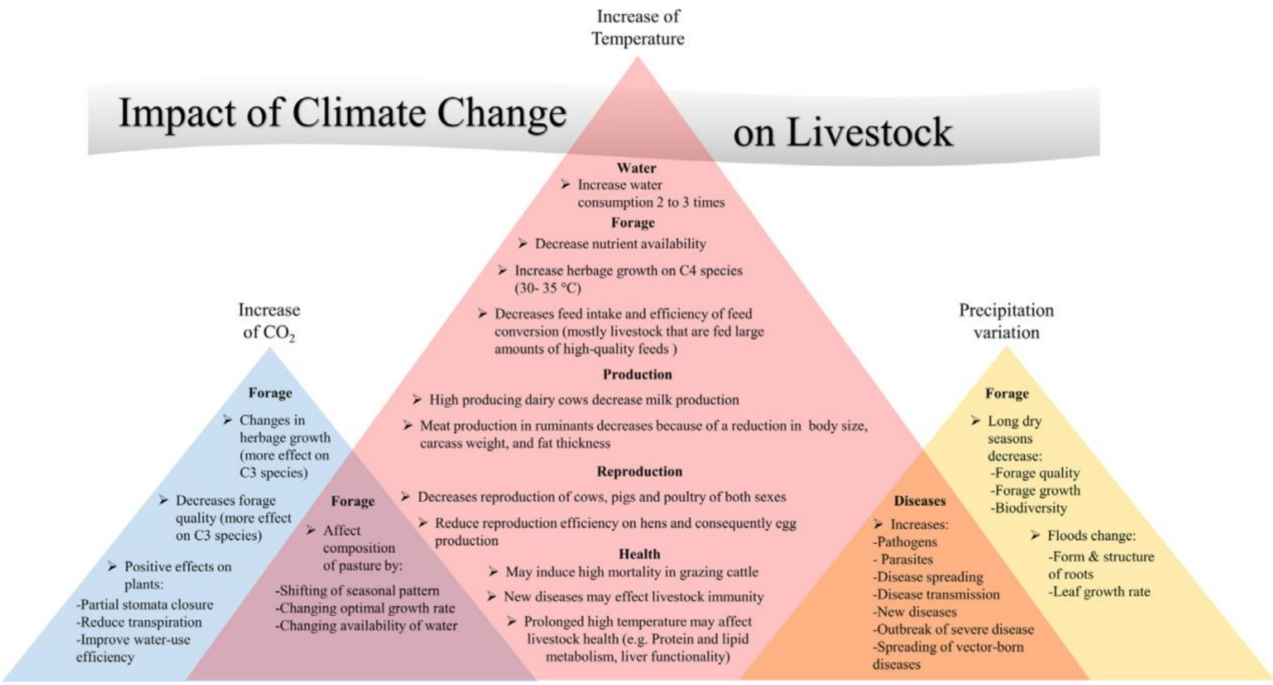
Importantly, there are large project increases in demand for livestock products in Africa over the coming decades that need to be considered in the light of ongoing climate change. Milk consumption is likely to triple under most scenarios in all sub-Saharan African regions by 2050, with East Africa, traditionally the largest consumer of milk, dominating the growth in consumption.

The consumption of meat from poultry and pork and eggs have the highest projected rates of growth across SSA. West Africa is projected to have a six- to seven-fold increase in the consumption of monogastric products (mostly poultry) to 2050, followed by Southern and East Africa (fourfold increases). A combination of demand management, intensification of land-based systems and structural change promoting more industrial monogastric systems could lead to increases in the environmental efficiency of livestock systems (for example, improved GHG emissions intensities) in sub-Saharan Africa without sacrificing pastoral and smallholder production (Herrero et al. 2014).

1.5 Impacts of climate change on livestock

It is clear that the impacts of climate change are not uniform and vary considerably across and within continents. A diagram outlining the major impacts of climate change on livestock globally by Rojas-Downing et al. (2017) is provided in Fig 1.1. Increases in temperature and atmospheric carbon dioxide along with variation in precipitation with separately have impacts and will interact to produce other effects. For example, forage availability for livestock will be affected through changes in growth rate and availability of water as a result of increased temperatures and CO_2. Other key elements of livestock production systems that will be affected are water availability, animal reproduction, diseases and production. More detailed information is presented in section 3.

Figure 1.1. Impacts of climate change on livestock globally



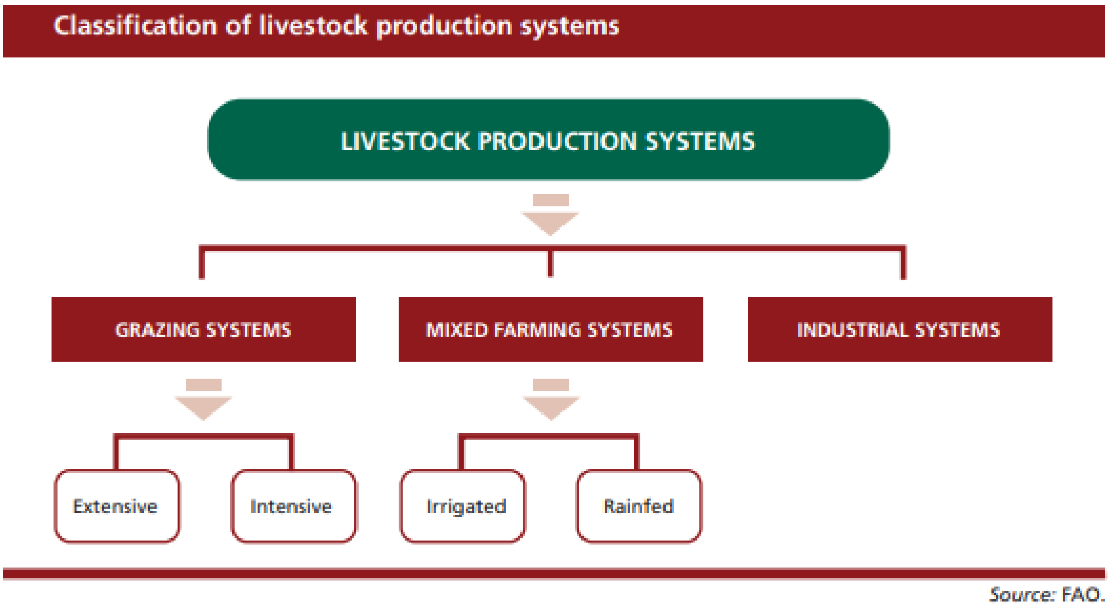
Source: Rojas-Downing et al. 2017

2. Overview of major livestock systems in Africa

2.1 Classification of livestock systems in Africa

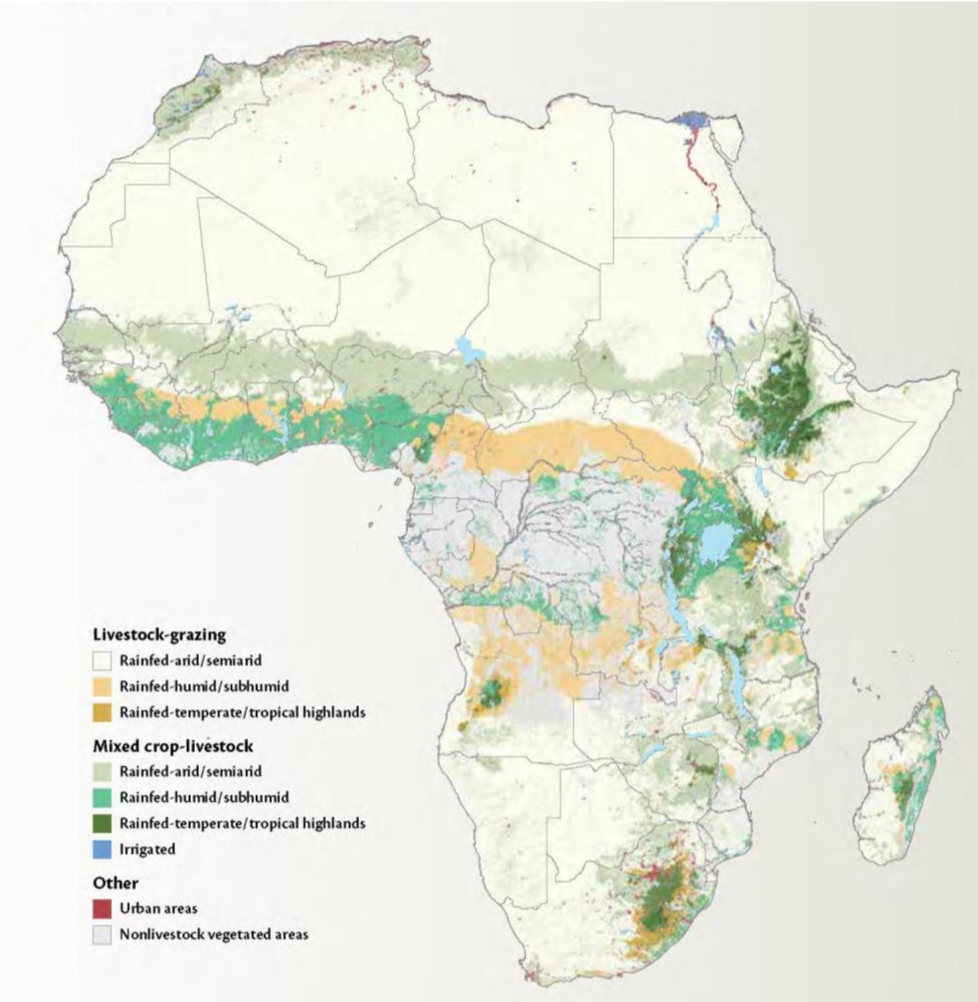
There have been many classifications of African livestock systems by many authors. Current climate change modelling systems are based on the schematic used by FAO (2009) in Fig. 2.1 below with the addition of datasets on land cover, length of growing period (LGP), highland and temperate areas, human population and irrigated areas developed by Robinson et. al. (2011). As seen in Fig. 2.1, livestock production systems can be broken down into grazing systems, mixed farming systems and industrial systems. Grazing systems are further classified into extensive and intensive, and mixed farming systems are delineated between irrigated and rainfed. Industrial systems include highly intensive pork and poultry production. Across Africa, three-quarters of agricultural land can be classified as grassland (Otte et al. 2019). Ibeagha-Awemu et al. (2019) estimate that 70% of livestock productivity takes place in small scale production systems, which are characterized by low animal population numbers and generally low inputs and outputs. As can be seen in the map in Fig. 2.2, large areas of the Horn of Africa, southern Africa and the Sahel are dominated by grazing systems, and mixed systems feature in western Africa and some parts of eastern Africa, with smaller areas in southern Africa.

Figure 2.1. Classification of livestock production systems



Source: FAO 2009

Figure 2.2. Map of livestock production systems in Africa by climate zone based on Robinson et al. (2011)



2.2 Characteristics of African livestock systems

Average farm size differs greatly by world region. In North and South America, Australia and New Zealand, large farms produce between 75% and 100% of all cereal, livestock and fruit production, whereas in sub-Saharan Africa, South-East Asia, South Asia, and China 75% of most food commodities are produced on small farms (≤20 ha), whilst in Europe, West Asia, Central America and North Africa it is medium-size farms (20-50 ha) that produce most of the food (Lowder et al. 2019; Herrero et al. 2017).

Table 2.1 compares the breakdown of African livestock production systems with equivalent systems in other continents. Sub-Saharan Africa (SSA) has the largest area (13.4 million km^2) and human population (80 million) under pastoral and agro-pastoral production systems. SSA also has the largest area under mixed extensive farming (5.1 million km^2), but only a relatively small amount of land (1.5 million km^2) for mixed intensifying compared to other continents or systems (Robinson et al. 2014). In sub-Saharan Africa, the quantity of large ruminant production is more than six times (milk) and three times (meat) greater than that of small ruminants (sheep and goats) (Herrero et al. 2013). Nevertheless, both small and large ruminant livestock play vital roles economically, socially and culturally throughout the continent.

It is difficult to separate out the effects of climate change vis-à-vis other drivers of change. Nevertheless, there is evidence that some shifts in livestock species have occurred over the last three decades at least partially as a result of increased climate variability – cattle being replaced by camels in northern Kenya is one example (Watson et al. 2016). In the future, wholesale production system changes are likely, for example in marginal cropping lands that may become increasingly unproductive from a crop perspective, or even shifts away from cattle to smallstock (e.g. Jones and Thornton 2009).

Table 2.1 Land area (millions of km2), human and cattle populations (in millions) for different systems in selected regions of the world

Farming system	Region	Area in 2000	Population in 2000	Cattle in 2000
Agro-pastoral and pastoral	CSA	5.4	40.5	64.18
	EA	5.5	41.3	12.67
	SA	0.5	19.2	6.19
	SEA	0.2	2.2	1.70
	SSA	13.4	80.2	36.68
	WANA	10.2	111.7	8.46
Total		**35.2**	**295.1**	**129.88**
Mixed extensive	CSA	3.5	100.7	67.24
	EA	1.7	195.4	20.32
	SA	1.6	371.9	71.96
	SEA	1.2	85.3	10.20
	SSA	5.1	258.7	55.53
	WANA	0.9	87.2	5.32
Total		**14.0**	**1 099.2**	**230.55**
Mixed intensifying potential	CSA	2.4	221.2	69.43
	EA	2.3	938.5	34.38
	SA	1.8	844.6	109.52
	SEA	1.1	347.2	13.84
	SSA	1.5	168.2	11.71
	WANA	0.6	154.4	6.01
Total		**9.8**	**2 674.1**	**244.89**
Other	CSA	8.8	125.8	41.83
	EA	1.5	104.2	9.79
	SA	0.4	69.5	8.65
	SEA	1.9	40.4	7.07
	SSA	4.1	109.2	6.77
	WANA	0.2	31.3	1.39
Total		**16.9**	**480.3**	**75.50**

Regional groupings of countries are as listed in Thornton *et al.* (2002).

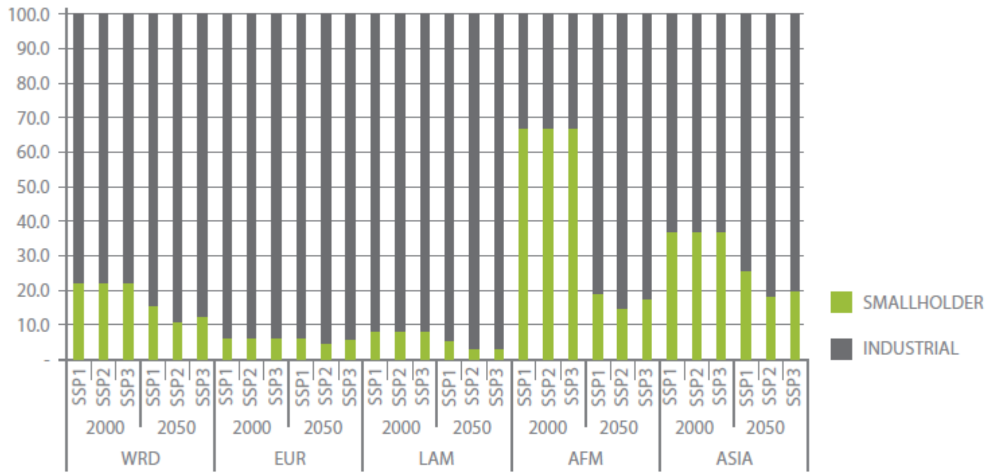
CSA = Central and South America; **EA** = East Asia; **SA** = South Asia;
SEA = Southeast Asia; **SSA** = sub-Saharan Africa;
WANA = West Asia and North Africa.

Source: adapted from Notenbaert *et al.* (2009).

Source: Robinson et al. 2014

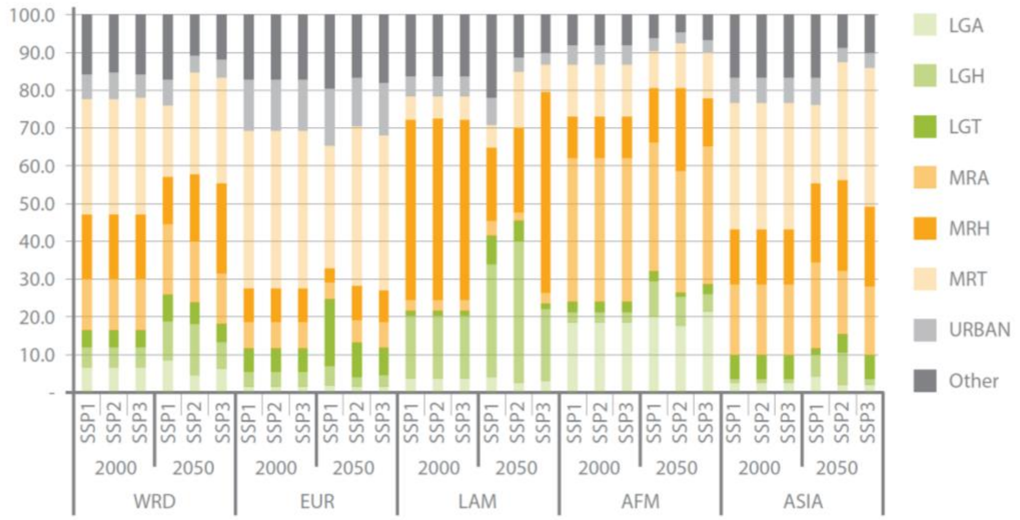
The different livestock systems provide the human populations, land area and cattle numbers; the bar charts and graphs from Herrero et al. (2014) below show the current (2000) systems and projected (2050) shifts in production systems for monogastric (Fig 2.4), ruminant meat (Fig 2.5) and raw milk (Fig 2.6) for all of Africa and the world modelled on different socio-economic outcomes (SSP1-3). Figures for Africa are under AFM (Africa and Middle East). In Fig 2.4, the current high dependence on smallholder systems in poultry and pork production is clear, but we see that monogastric production will shift from a majority of production in smallholder systems to more than 80% of production in industrial systems. Rust (2019) indicates that this urbanization of such livestock production systems may then be followed by a return to rural areas driven by environmental pollution and resource pressures.

Figure 2.4. Monogastric production globally (percentages of system total)



In Fig. 2.5 we see that in Africa there are only slight shifts projected in ruminant meat production systems, with mixed crop-livestock systems in arid areas still playing a major role in meat production. Production in grassland-based temperate highlands may increase, and there may be slight decreases in urban production.

Figure 2.5. Ruminant meat production by system globally (percentages of system totals)



LGA = grassland-based - arid

LGH = grassland-based - humid

LGT = grassland -based temperate/highlands

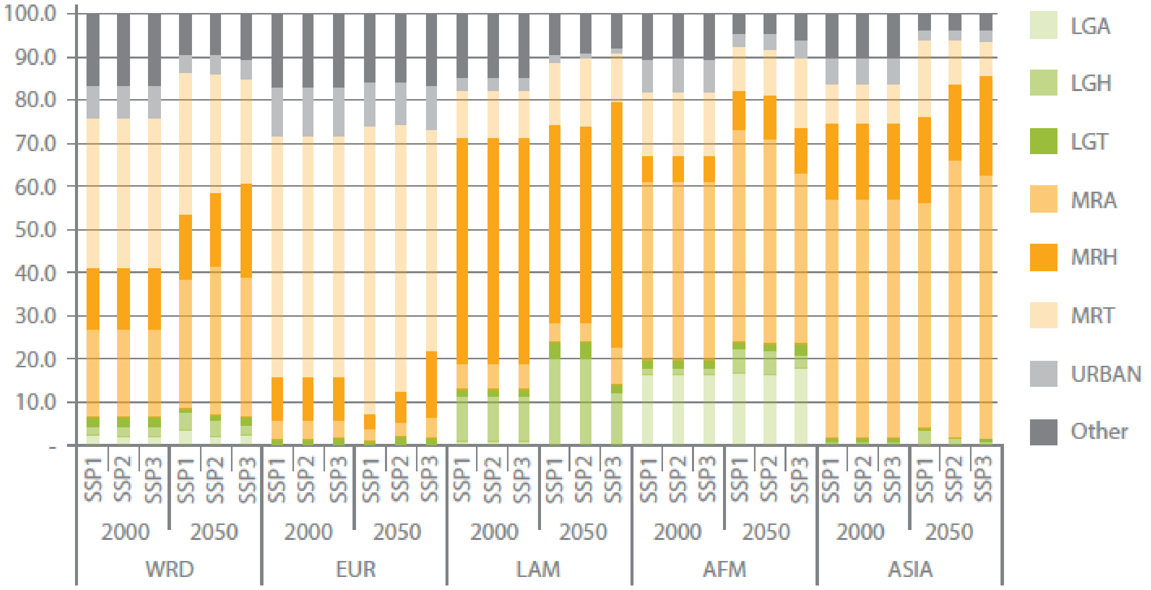
MRA = mixed crop-livestock systems - arid

MRH = mixed humid

MRT = mixed temperate/ highlands

In Fig 2.6, we can see that milk production in 2050 is projected to increase in mixed humid systems under the first two shared socioeconomic pathways but will not grow my much in the third (higher GHG emissions) pathway. Urban and other systems are also projected to reduce as a share of milk production in Africa in 2050.

Figure 2.6 Raw milk production by system



LGA = grassland-based - arid	MRA = mixed crop-livestock systems - arid
LGH = grassland-based - humid	MRH = mixed humid
LGT = grassland -based temperate/highlands	MRT = mixed temperate/ highlands

2.3 Importance and role of livestock to gender and youth

Table 2.2 below shows the different roles of the different genders and age-groups in many livestock keeping societies. The data is extracted from Simpkin (2005) based on ICRC experiences in the Horn of Africa. Since 2005 there have been many advances in terms of the understanding the role of women and youth in livestock keeping. Originally it was thought that women had very little to do with ruminant livestock production in Africa, however over the years the role of women in terms of ownership of smallstock and poultry, control of milk offtake and sale, and decision on the use of the money derived from milk and smallstock sales has become much more recognized (Rao et al. 2019).

The changing role of women has been particularly obvious in mixed farming and intensive systems where women are often now in charge of dairy and medium to large-scale pig and poultry production enterprises. In some societies such as the Maasai, women are increasingly involved in managing the small exclosures reserved for milking cows and young calves (Wangui 2014), however according to Aregu et al. (2016), in the Ethiopian highlands, women's access to shared grazing areas is still restricted by customary law. These traditions may change as the value of empowering women is recognized. We should also note that women may lose control of some income or value chains such as dairy if men perceive these as lucrative (Tavenner and Crane 2018). There is still room for improvement in terms of land and livestock asset inheritance, and many countries are only now just beginning to adapt policies to support such rights.

Table 2.2. Role of the different ages and genders in livestock keeping in the Horn of Africa

Men	Women	Young men	Girls
Decision making	Distribution of food including milk.	Milking camels	Milking cows and small stock
Herding	Herding	Herding	Herding
Milking camels	Milking cows and smallstock.	Milking	Milking cows and small stock
Slaughtering animals	Preparing food and milk by-products.	Slaughtering animals	
Buying and selling animals	Fetching fodder for weak animals.	Stealing animals - restocking	
Watering animals	Watering animals	Watering animals	Watering animals
Protection of family herds	Loading load camels and moving camp.	Protection of family herds	
Pasture surveys	Preparing hides and skins	Paying bride-price	Preparing hides and skins
	Looking after lambs and kids	Pasture surveys	Looking after lambs and kids
	Preparation of milking bowls and storage containers.		
	Selling leather handicrafts		

Source: Simpkin 2005

The role of youth is also emerging beyond just herding and employment into leading small family businesses especially where the faster returns from smallstock, rabbit and poultry production are more attractive. In many countries (e.g. Kenya), agriculture and livestock farming is not seen as a "desirable" vocation or profession, as it involves hard and dirty physical labour, however as mechanization and smart farming grows we are likely to see an increase in the number of youth participating in the farming industry even if not as producers.

Many references in the literature (IPCC 2018) highlight that women and youth are more vulnerable to climate change in agriculture and livestock keeping, as they often have less access to information, markets, credit or insurance in addition to already having heavy workloads in the home. However, many governments and organisations recognize that investing in women is often a better return than in investing in men, possibly because women have stronger family ties and stay at home and depend on livestock more.

2.4 Livestock, institutions and change

There is evidence and the projections certainly show that there is increased industrialization of livestock production especially in southern Africa with ruminants, but also across all of Africa with poultry and pigs, although to different degrees of scale. Most of this is in the hands of the private sector. There are also changes taking place in livestock production in the extensive free-ranging management systems of east, west and sub-Saharan Africa where there is increasing privatization of rangelands, partly due to population growth and resource degradation, but also due to land grabbing and a breakdown of the traditional institutions.

Traditional institutions, especially well documented in pastoralist societies, played a major role in resource management and grazing practice control. With colonialism, many of these traditional institutions were replaced by a government structure of administrators and chiefs, which continued into the present-day independent state government systems. Different systems evolved according to the political inclination of different states and governments with some strongly socialist (Ethiopia and Eritrea) policies and strategies, whilst others followed a more capitalistic route with privatization of land and growth of the private sector including cooperatives and commercial livestock associations especially prevalent in the dairy sector.

It is generally recognized that in many countries with large populations of livestock managed in free-ranging nomadic or transhumant systems that are dependent on natural pastures many of the traditional institutions have been weakened or have totally broken down. The possible exception is Ethiopia, where in the southern Borana rangelands the *deda* system is still very strong and continues to enforce many traditional natural resource management mechanisms. Pastoralist Union systems that were common in Sudan and across much of central and western Africa countries were also widely recognized as being effective; however, the effectiveness and success of such bodies, and cooperative movement in general in some countries, has been more variable in recent times. Although there is much interest in re-constituting and re-energizing some of the traditional institutions, others believe that the attitude of the youth and modern-day philosophies make them redundant and simple relics of the past. The reasons for these shifts are not always (or even mostly) to do with climate change. Fragmentation of rangelands and increasing population density (leading to the closing off of traditional transhumance routes) all contribute. Decision makers can help mitigate some of these changes through effective policies at national and regional levels to help guide the shifts in livestock production systems in a way that allows livestock keepers to continue production while adhering to good practices.

3. Major challenges to African livestock systems

3.1 Overview of non-climate change related challenges

A comprehensive project looking at barriers, blocks and enablers or catalysts for climate change adaptation aligned to community aims and priorities (Few et al. 2018) found that cultural factors and community involvement may play an important role in uptake and implementation of adaptation (Rao et al. 2019) as do institutional capacity (Oberlack 2017), governance (Sidibé et al. 2018), finance (Shackleton et al. 2015; Castells-Quintana et al. 2018) and technology (McNamara and Buggy 2017) and that many of the barriers (or enablers) not only individually hamper (or support) adaptation, but in combination make it even harder to succeed in adaptation. Thus, a multi-pronged and cross-sectoral approach may be required to ensure success.

Waha et al. (2018) note there are multiple institutional, social, political and economic barriers to adaptation in African agriculture. They identify the following as "multiple stressors": poverty; limited human resources due to low development levels; poor infrastructure; land use challenges; desertification (with 46 out of the 55 African countries affected); low levels of livelihood diversification and low adaptive capacity; limited economic resources; lack of appropriate technologies; conflict over resources and governance challenges. Conflict, global economic conditions and adverse climate have also been noted as challenges (FAO et al. 2019).

High investment costs in technology (e.g. drip irrigation, boreholes, etc) and lack of access to finance for small farmers are recognized as challenges. UNEP (2015) estimated adaptation costs of USD 7-15 billion/year by 2020 for Africa. Dawson et al. (2016), estimate that +2°C increase in temperature globally will make 50% of the African population vulnerable to the risk of undernourishment and will cost Africa less than 1% of African GDP, but having to adapt to +4°C increase would cost up to 6% of the continent's GDP (UNEP 2015).

3.2 Challenges presented by climate change up to 2050

The challenges have been clustered broadly according to the categories highlighted by Rojas-Downey et al. (2017) with some additional issues identified and expanded upon. Although there are different climate change scenarios and RCPs, it is believed that the level of divergence between RCPs is small up to 2030, moderate up to 2050 but very different by 2100 (Woetzel et al. 2020).

Various reports (FAO et al. 2018; IPCC 2019) note that in Africa, where a large proportion of the population depend on rainfed crops and pastoral rangelands, climate change has an effect on all four dimensions of food security and nutrition, and that food security and undernutrition are worsening among some populations.

3.2.1 Quantity and quality of feeds including natural rangelands and pasture

Within livestock systems, climate change is expected to have greater impact on grazing systems than production systems in which animals are confined due to effects of temperature and rainfall changes on pasture composition and forage availability (Rojas-Downing et al. 2018). In terms of land availability for pasture, model projections are very varied but estimate a 0.5–11 MKm^2 reduction of pasture land globally (IPCC 2018). This is mainly due to the increase in land converted for cropping of energy crops and re-afforestation. Overall a reduction of animal feed is considered a major challenge in most publications.

Boone et al. (2018) project that grassland productivity in west African rangelands will decline by 46% by 2050, and that reducing levels of primary plant production across African rangelands will reduce livestock production, productivity and profitability. This is projected to lead to an overall decline in livestock numbers by 7.5–9.6%, an economic loss valued at $9.7–12.6 billion. However, the impacts and changes show considerable variation between the different regions in Africa, with the effects worse in north, south and west Africa than in eastern and Central Africa.

There is a strong argument for intensification of livestock production, but "despite ongoing gains in livestock productivity and volumes, the increase of animal products in global diets is restricting overall agricultural efficiency gains because of inefficiencies in the conversion of agricultural primary production (e.g., crops) in the feed-animal products pathway (Alexander et al. 2017), offsetting the benefits of improvements in livestock production systems (Clark and Tilman 2017)" (de Coninck et al. 2018, p.327). Makkar (2018) and others have highlighted the concerns about using corn, soybean, wheat, barley, sugar beet and other crops that can be consumed by humans as animal food in a world that is facing increasing food security challenges.

This argument could be to the benefit of African livestock keepers, as the majority of livestock in Africa are not consuming feeds that can be consumed by humans as is the case in intensive or industrialised systems. The majority of African livestock obtain the bulk of their nutritional needs from natural vegetation that is unpalatable and undigestible to humans and would otherwise be wasted. In addition, many of these animals are consuming this vegetation that grows in arid areas or where soil conditions are unsuitable to growing food crops.

Thus, there is a paradox between intensification of livestock production leading to increased feed efficiency and reduced GHG emission intensity, versus the low yielding, free ranging, high emission intensity pastoral livestock that contribute significantly to human nutrition off land that is of high biodiversity but low potential for human food crops. When combined with arguments highlighting the wide range of ecosystem benefits associated with well managed grazing lands, there is need to review the emission intensity measurement and its suitability as an indicator for climate change attribution in the African system.

The issue is further complicated by the "recommendations" towards a healthier, less environmentally damaging (i.e. more GHG friendly) white meat diet from fish, poultry and pigs, which will however, due to the monogastric high protein requirement, also increase competition with humans for grains and protein rich feed crops such as soya unless production systems shift to using by-products that would otherwise not be consumed by humans, thereby avoiding food-feed competition. Solutions may lie in the use of insect farming as a source of protein, and for integrated thinking and approaches in tackling the problem, and the uptake of existing holistic, nexus and cross sectoral programming as recognized by Escarcha et al. (2018).

3.2.2 Water availability and quality

The majority of publications and projections also highlight water stress and water availability as a major challenge to African livestock systems, especially in the driest areas (Palmer et al. 2008). The IPCC special report on warming of 1.5 °C (2018) states that as temperatures increase from 1.5 °C to 2 °C the greater the likelihood of water stress increases, especially in southern Africa. One reason is due to rising temperatures leading to increased evaporation and drying, causing more frequent and prolonged dry seasons and drought in many parts of southern and western of Africa. Even in parts of east Africa where there may be greening, there will likely be increased stress because although the rainfall may actually increase, it is projected to be in more intense rainfall events with greater run-off and little penetration or recharge of the groundwater aquifers, unless there are significant improvements in water harvesting, plant cover protection and land management. Some reports even highlight the significant water footprint of re-afforestation having an effect on water availability; however, it is not known to what level this may be a problem in Africa (IPCC 2018).

Human and livestock populations are expected to experience water stress as increasing temperatures induce changes in river discharge and the amount of water in basins. Changes in rainfall patterns may also result in changes in vegetation, thereby affecting livestock species and herd composition. A warmer and wetter climate in eastern Africa, as predicted by global climate models, could result in certain grasses reducing in productivity and shrubs increasing in productivity—this decrease in grass cover could result in greater competition for forage among grazing species (Eriksen et al. 2013). Improvements in water utilization efficiency, including improved catchment, storage and distribution systems, zero-tillage, drip-irrigation (for fodder, feeds and human food crops), keeping livestock breeds with lower water needs (e.g. camels, goats and oryx), planting trees and fodder trees and shrubs to reduce ambient air temperatures are all potential solutions.

3.2.3 Livestock pests and diseases

Livestock diseases are expected to spread further due to both the spread of hosts and pathogens, with temperate countries (northern and southern Africa) starting to see more tropical vector borne diseases as minimum temperatures increase and the vectors may survive in hitherto areas previously too cold. Rift Valley fever (RVF) outbreaks have been found to be linked to El Niño–Southern Oscillation (ENSO) events, with particularly high severity expected in east Africa (Kenya and Tanzania especially) and South Africa (Anyamba et al. 2009). Models by Taylor et al. (2016) and Mweya et al. (2017) indicate shifts in the range of RVF outbreaks by 2020 and 2050 and its spread to new areas and countries.

Jones et al. (2019) have shown a link between temperature increase and the range of *Culicoides imicola* which carries the bluetongue virus and has caused the death of millions of animals and major financial losses already in Europe where previously it never occurred. They suspect that outbreaks that currently only occur once every 20 years, by the 2070s will be common occurrences. The only reduction in range may be of the trypanosomiasis bearing tsetse fly, where rising temperatures and land-use change may reduce their range (Bett et al. 2017); however large gaps in knowledge about disease pathogen and vector spread still exist (Cable et al. 2017; Hristov et al. 2018).

Nyangiwe et al. (2018) have documented the spread in range of several ixodid ticks, which are known to cause diseases such as cowdriosis, anaplasmosis, bovine babesiosis and theileriosis, all of which are of economic importance. Bett et al. (2017) estimate that the geographical range of 50% of tick species could expand. In addition to their natural spread, climate change may have contributed to their spread through transportation of livestock within and between countries in search of grazing or markets, or due to the increased transportation of fodder and hay to drought or flood affected places.

Recent unseasonal and unexpectedly heavy rain in eastern Africa has seen the emergence of locust swarms and consequent destruction of large areas of natural pastures, which have not been experienced for the last 50–70 years in parts of Kenya, Ethiopia and Somalia. There is a risk that, due to insufficient levels of control combined with continuing unseasonal rains, their numbers will increase hugely with the potential of causing famine in some parts of east Africa by mid-2020.

3.2.4 Heat stress

Rojas-Downey et al. (2017) detail how (i) feed intake, digestion, metabolism and utilization; (ii) animal production and reproduction; and (iii) health and mortality are all affected by heat stress. Heat stress not only reduces the economic returns from livestock, but also can become an animal welfare issue.

Livestock management patterns in Africa have already adapted to heat stress, with animals being released early in the morning and allowed to rest under shade trees during the hottest parts of the day; some are left to graze late into the evening and night especially on moonlit nights. This helps improve feed intake and water loss but can result in increased incidences of theft or predation.

Heat stress affects reproductive processes differently in different species: from embryonic development and reproductive efficiency in pigs (Barati et al. 2008) to ovarian follicle development and ovulation in horses (Mortensen et al. 2009).

D'Odorico et al. (2018) note that there has been much research into the effects of heat stress on animal production, but little has been done in terms of long-term or life-cycle animal productivity and interannual climate variability, which this paper highlights as a major risk to livestock in Africa.

In the short-term, costs of reducing the effects of heat stress, such as large-scale livestock sheds equipped with spray or mist-fans can increase production costs as well as lead to other potential disease risks. Longer term it has been shown that maintaining groundcover, planting trees, creating windbreaks and greenbelts can all change the micro-climate and reduce the risk of heat stroke and stress in livestock.

3.2.5 Biodiversity loss

Biodiversity in ecosystems: Models of temperature increases between 1.5–2 °C indicate major changes in land-use for food production, livestock feed, afforestation, fibre and bioenergy production, carbon storage, biodiversity and other ecosystem services as well as human settlements (IPCC 2018). The drive towards intensification of livestock keeping, with its associated demand for increased areas of cultivated feds and fodders which are most efficiently produced as a mono-crop or mixed grass/legume or cereal/grass mixed swards, are likely to affect biodiversity negatively.

Some of the biomes or ecosystems most at risk to biodiversity loss as a consequence of increasing temperatures and resulting higher frequency of fires and drier winters are the Fynbos and succulent Karoo biomes of South Africa (IPCC 2018). Different temperature increase scenarios may reduce the suitable climate areas for Fynbos by between 20–80% (Engelbrecht and Engelbrecht 2016).

Forest, wetland and rangeland management, conservation and restoration combined with technology and ecosystem approaches to climate change adaptation and mitigation are ways of protecting biodiversity. REDD+ and its multiple potential co-benefits are reported to be important for local communities, biodiversity and sustainable landscapes (Ngendakumana et al. 2017).

Biodiversity within livestock: Compared to intensive or industrial livestock production systems, such as poultry, pig, sheep and dairy or beef cattle, the extensive pastoral livestock and village or backyard poultry production systems common to Africa are much more diverse in terms of genetic stock. Amongst most of the African livestock there are populations of animals kept for their hardiness, drought tolerance, pest and disease resistance, ability to travel long distances and survive on minimal feed intake, as well as for coat colour, body conformation and horn size. This provides a much larger gene pool and biodiversity than domestic animal populations kept in temperate and tropical intensive systems bred for agro-industry and commercial farming to maximise profits and efficiencies, such as the Friesian Holstein dairy cattle, Rhode Island Red chicken and Belgian Blue and Charolais beef cattle.

There is a need for more research and development of these indigenous breeds and to build on their inherent traits as a means of adaptation to climate change, however in terms of efficiency in production in terms of emission intensity they will rarely be able to compare to the breeds developed for the commercial farming sector and their hybrids.

One adaptation already commonly seen in Africa is the mixed herd approach to farming, where small holders and pastoralists keep a mixture or different combinations of cattle, camels, sheep, goats, chickens and donkeys in order to benefit from all their different traits and uses and to spread risk from disease outbreaks and drought across the different species. Breed differentiation within-species is also well defined in Africa, (e.g. Boran, Ndama and Drackensburger cattle; Boer, Galla and Dwarf goats; Persian black-headed, fat-tailed and Red Maasai sheep; Siftar, Hoor and Gelub camels) however it is rarely based on productivity alone and hence will contribute in adaptation but less so in terms mitigation if measured as emission intensity efficiency.

3.2.6 Agro-ecological zones

Climate change will also challenge the delineation and definitions of agro-ecological zones. As temperatures and soil-moisture contents change, the boundaries of existing agro-ecological zones will change, but as they transverse across different soil types, altitudes, latitudes and longitudes their characteristics will affect local ecologies and will require new definition or labelling. As these changes take place, climate change related losses in crop and livestock product yields will increase, especially at lower altitudes, with Sub-Saharan and north Africa being particularly at risk (Aggarwal et al. 2019).

3.2.7 Food security, income and livelihoods

Many authors indicate that the higher the temperature the higher the vulnerability to food security in the Sahel with the western Sahel possibly experiencing the most serious drying and food insecurity issues largely due to reductions in maize, rice, wheat and other cereal yields (IPCC 2018). Trade will also be affected. FAO et al. (2017) reported 11% of the world's population suffering from recent decreases in food security with more than 815 million people undernourished in 2016, with highest percentages in Africa (20%). All four pillars of food and nutrition security (availability, access, utilisation and stability) are affected by climate change (Thornton et al. 2014; FAO 2016).

With an estimated 7–10% of rangeland livestock expected to be lost with a 2 °C increase in temperature (IPCC 2018), livelihoods and rural incomes in Africa particularly are likely to be badly affected. Herrero et al. (2010), calculated that up to 1.8 million extra cattle, with a total production value of up to USD 630 million, could be lost in Kenya by 2030 because of increased drought frequency.

Modelling results in Zimbabwe farming systems suggest that small increases in temperature (+1–2.2 °C) are projected to have small but positive impacts on livestock net revenues, but higher changes in temperature [(+2–2.8 °C (RCP4.5) and +2.7–3.6 °C (RCP8.8)] reduced the net revenues from livestock by 8–32% and 11–43% respectively with farms or households with larger herds/flocks being hit hardest (Descheemaeker et al. 2018).

Declines in crop yield and harvest reliability will not only reduce the amount of grain available as livestock feed, but also lead to price fluctuations in the local markets and force farmers to buy more grain for home consumption, reducing their disposable income to the possible detriment of the livestock in terms of feed/fodder and veterinary and other production inputs. Integrated crop-livestock-fish farming systems, crop and livestock diversification, improved water efficiency through use of irrigation and other technology (e.g. water harvesting, zaï pits, bunds and terracing), improved soil management (erosion control, fertilizer use, zero-tillage, CSA, etc) and ecosystem-based approaches are all recommended as adaptation responses to safeguard food security and protect livelihoods (IPCC 2018).

3.2.8 Livestock and coping with climate variability

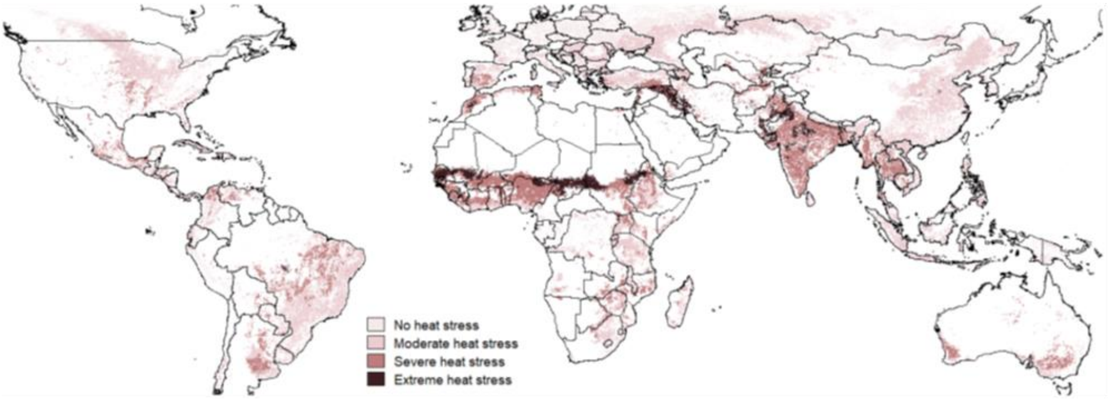
An increase in warming will lead to an increase in climate variability (Thornton et al. 2014). Variability of climate impacts on livestock production systems although sufficient information and data is hard to find. Thornton et al. (2014) highlight links between climate variability and increasing food insecurity in crop and livestock systems especially in low- and middle-income countries (LMICs). Megersa et al. (2014) provide evidence from pastoralists in Ethiopia where herder perception was that rainfall was more unpredictable (i.e. increased rainfall variability) and led to increased cattle mortality (26%) and forced off-take (19%) in the 2010/2011 drought. Similar trends are seen in Kenya between the period 1977 and 2016 with a major (30%) decrease of cattle numbers in the ASAL counties, compensated for by an 300% increase in smallstock numbers and camels (Ogutu et al. 2016).

Increased climate variability will increase the likelihood of extreme heat events, with serious impacts on animals of increased heat stress. Significant reduction in the areas suitable for livestock production may occur. Fig. 3.1 shows preliminary projections of the Temperature Humidity Index

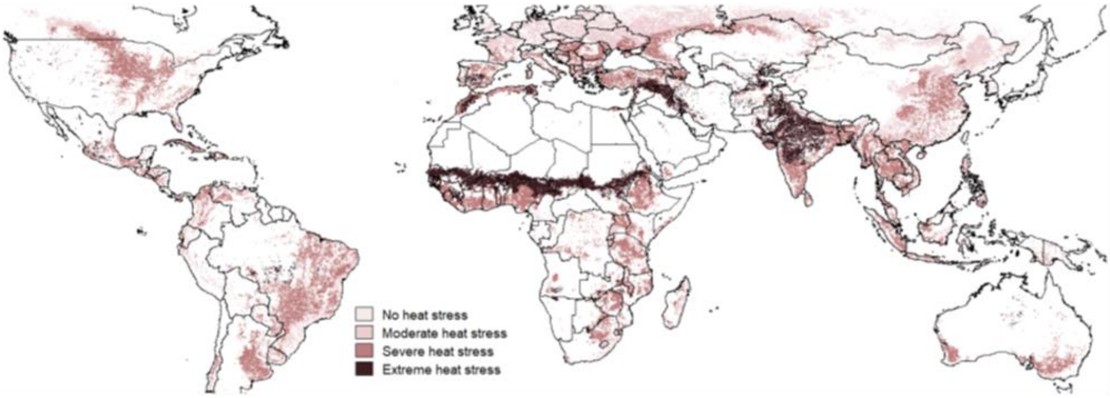
(THI) using CMIP5 data under RCP8.5 to the 2090s. The proportion of the mixed crop-livestock systems (which contain most of Africa's dairy production) that will be subjected to at least one month of mean THI values >80 (corresponding to severe and extreme heat stress) may increase from 32% currently to 67% (Thornton et al. 2020, work in progress). Heat stress, along with possible increases in drinking water scarcity, will affect all grazing animals, though the effects on small ruminants, particularly goats, are generally more muted than in cattle. It is often assumed that rural poultry are hardy and well adapted to stressful environments but there is not much solid information about their performance under future climate stresses (Nyoni et al. 2019).

Figure 3.1. Maximum monthly value of the Temperature Humidity Index (THI) in mixed systems under (A) current conditions and (b) 2090s in RCP8.5

A: Current conditions (2000)



B: 2090s, RCP8.5, projections based on the ensemble mean of 17 CMIP5 climate models



Source: Authors

Variability in climate and weather events, and the difficulty in predicting or being able to respond to variability, may have larger negative impact on livestock and agricultural systems than slow onset or gradual climate change, e.g. rising temperature. In Africa, rainfall variability is especially high in north, west, east and southern Africa, whilst low variability is recorded in the centre of the continent.

3.2.9 Conflict

Conflict within and between pastoralists, agro-pastoralist and settled farmers can often be amplified by climate change and the increased pressure put on the natural resources of the nomadic system. Early research papers in the 1990s indicated links between land degradation, climate change and conflict (with examples of Rwanda and Darfur), but more recent papers recognize that conflict can occur but mostly in combination of climate change (or drought) and other factors such as poor governance. Some authors (D'Odorico et al. 2018) continue to warn of increased conflicts over land, food, water and energy, highlighting that both climate change and population growth exacerbate the potential for conflict. The IPCC Special Report on climate change and land concludes that "there is low confidence in climate change and desertification leading to violent conflicts", but "there is medium evidence and low agreement that climate change and desertification contribute to already existing conflict potentials" (Mirzabaev et al. 2019, p.275). The report does recognise with medium confidence the risk that slow decision making and response to climate change disasters (or risk management) can lead to increased strife and conflict.

Media reports of increasing incidences of conflict and loss of human life are widespread across most of west, north and east Africa, however not all of these maybe a direct result of climate change, but can also be related to terrorism and violent extremism, where some may claim to be an indirect result of climate change as the rural youth are increasingly marginalized and impoverished partly as a result of climate change.

Human and wildlife conflict is also a growing problem, not only between livestock keepers and national park authorities and the animals themselves (e.g. wildlife killing people and livestock and people killing wildlife) but also as wildlife invade crops as droughts become more frequent and as humans expand cultivation into areas near wildlife concentrations. The annexation of former grazing lands into forest reserves, national parks and wildlife conservancies can also lead to conflict. The establishment of conservancies, even those that include planned livestock grazing systems, have on occasion lead to conflict, as often distant communities who may have user-rights to such areas, are not involved in their planning and establishment.

3.2.10 Global trends and beliefs in climate change and livestock production/consumption

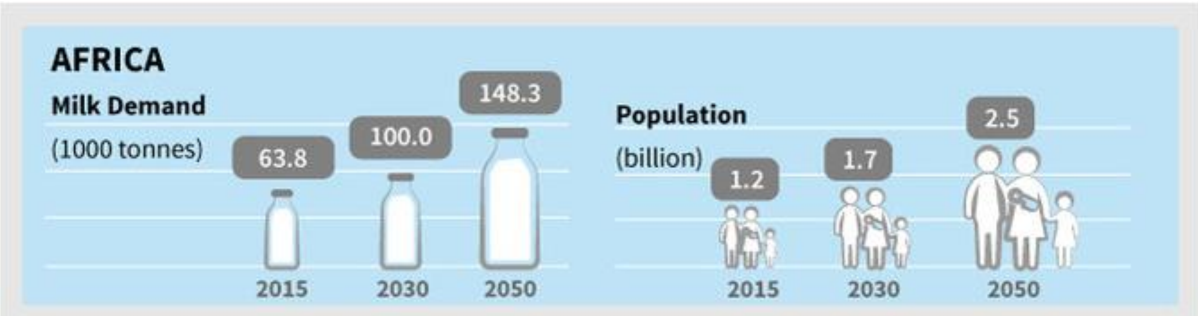
Many challenges have been mentioned earlier revolving around diet and meat intake, animal welfare and trends towards vegetarianism and veganism. These have the potential to influence consumption trends both outside of Africa, thereby affecting trade, and even within upper class urban African populations. Additional issues relate to land tenure and land fragmentation, issues that may be a pre-requisite for intensification.

4. Projected future trends and opportunities in the African livestock sector

4.1 Summary of projected livestock sector development

FAO's Future Perspectives study and the Africa Sustainable Livestock 2050 (ASL 2050) study predicts large increases in demand for livestock products as the continent's populations grow and flourish with higher disposable income and increased urbanization. The ASL 2050 reports predict that "by 2050, the African population will reach 2.5 billion, from 1.2 billion today, and that 56 percent of the population will live in urban areas, vis-à-vis 40 percent today (UN, 2017 and 2018). Gross domestic product, currently at USD 4.7 trillion, is estimated to almost triple by 2050 (FAO, 2018), resulting in increased purchasing power for African consumers. An emerging middle class will support the democratization of the continent, further reinforcing economic growth and development (AfDB, 2011)" (FAO 2019 p.1).

Figure 4.1. Projections of milk demand and human population in Africa up to 2050



Source: FAO n.d.

In addition, based on past trends seen in other regions, the same report postulates:

> "the quantity and value of agriculture production will increase, but the contribution of the sector to GDP and employment will reduce. Currently, agriculture accounts for 17.5 and 11.7 percent of GDP and contributes 57 and 22.3 percent to total employment in sub-Saharan Africa and North Africa, respectively. In high income countries, these shares are less than 2 and about 3 percent, respectively (WDI, 2018). The second transformation is that livestock will become one of the most important sectors of agriculture in value terms. Today, it accounts for 25 percent of agricultural value added in Africa, and to 55 percent and 67 percent in North America and Western Europe, respectively (FAO 2018b). The

> reason is that, as economic development progresses, increasingly well-off consumers will move away from a predominantly cereal-based diet and start purchasing the high-value proteins that meat, milk and other livestock products offer, as well as fruits and vegetables" (FAO 2019 p.1).

They predict that the "Livestock Revolution (Delgado et al., 1999), will profoundly affect the development of African livestock in the coming decades" (FAO 2019 p.1).

Somewhat different approaches have been suggested by other authors, with D'Odorico et al. (2018) summarizing the future of African livestock under two key drivers: (i) finding sustainable increases in production through low technological approaches; and (ii) consumption-based approaches encompassing changes in consumption rates and waste reduction and reuse.

Increases in the production of beef and milk are expected largely to be achieved through improved productivity per cow at equivalent rates to those achieved by Brazil, China and India over the past 35 years[1] (FAO 2018b). Following a similar pathway, Botswana reduced its cattle stock by 67% in the 35 years from 1980 to 2015. Projections by FAO's ASL 2050 (2018c) expect a reduction in Uganda's cattle population by 14% by 2050 through gains made in productivity, however for Burkina Faso and Nigeria cattle numbers are expected to increase by between 30-100% depending on the different scenarios modelled. However increased production in poultry meat and eggs, sheep, goat and pig meat will mostly be achieved through massive increases in animal numbers (FAO 2018c).

By 2050, human populations are projected to increase by an average of 139%, (with highest growth in Uganda at 290% and lowest in Egypt at 65%), and individual purchasing power will increase on average by 345% from the current average across the six[2] countries of USD 1654 per person to USD 7036, with the highest increase in purchasing power being in Egypt (544%) and lowest in Ethiopia (225%). Consequently, across the six countries the percent increase in demand for beef, milk, poultry meat and eggs by 2050 is projected to be 282, 193, 406 and 316% respectively. These figures are comparable to those of Enahoro et al (2019) whose survey across all sub-Saharan

1 Brazil cattle productivity increased by 35% and Chinese poultry productivity by 26%; between 1980 and 2005, as a result of the Operation Flood Program, milk productivity in India increased by 64% in aggregate, with higher increases for dairy and buffalo than for small ruminant milk (FAO 2018b).

2 Data from Kenya not included.

African countries calculated the mean increase in human populations to be 108%; individual purchasing power to increase by 280% from USD 1652. Projections for GDP growth from the two different sources averaged 500% and 689% respectively.

From their models, Enahoro et al. (2019) concluded that increasing higher productivity per animal was the key to improving resource efficiency with the added advantage of lowering food prices for consumers. Market interventions did not incentivize increased productivity, thus limiting the potential to improve resource use efficiency and reduce environmental impacts, but the market interventions did reduce production costs for producers. Both interventions had a positive impact on kilocalorie availability and reduced risk of hunger, but overall investing in improved productivity showed the best returns. They noted that empowering women in the livestock sector could have a major impact on improving health, nutrition and resilience in poor regions, however simply increasing the quantity of animal source foods does not automatically result in improved nutrition. Contrary to other models, they found that the shift to monogastric consumption in sub-Saharan Africa was probably less than in other parts of the world, but that such shifts will lead to an increase in competition for feed grains, and that since consumption of animal source feeds are generally low in sub-Saharan Africa, that consumers in the region could actually benefit from an increase in consumption.

In a modelling study of Ethiopia, Rwanda, Burkina Faso and Niger along with two Asian countries, Enahoro et al. (2019) found most African countries studied would continue to be net importers of milk, poultry and beef, except for Ethiopia who would be a net exporter of beef and Burkina Faso a net exporter of pork and lamb. Many African countries, due to rapid population growth, urbanization, economic growth and increasing disposable income, balanced against currently low levels of productivity and production efficiencies, will remain net importers of some animal source foods. This suggests there is a need to do more and broader studies across the whole continent to identify which countries have the potential to be net exporters of different livestock products and to develop a continent-wide strategy to improve efficiencies. The need for feeds and fodder were projected to increase massively for all countries in all scenarios. They pinpointed Ethiopia would benefit from investments in feed storage and efficient feed marketing systems.

ASL 2050 projections also show major shifts in how the livestock management systems will change towards industrialisation. Using Nigeria as an example, currently the proportion of the national herd of 18.7 million cattle under pastoral, agro-pastoral and commercial (intensive) production systems are 82%, 17% and 1% respectively; by 2050, under the most preferred prediction model, the proportion of the estimated 37 million cattle will have changed to 42%, 25% and 33% under the above production systems. Nigeria's poultry sector will increase from the current estimated 180 million birds to 900 million birds, with the number of birds kept under extensive and semi-intensive systems dropping from the current 46% and 33% to 10% and 20% respectively, and the proportion of birds in intensive management systems increasing from the current 21% to 60% in 2050 (FAO 2019).

However, Enahoro et al. (2019), using quantitative scenario modelling, show it is not easy to predict where the best investment in livestock stands, and it varies between countries and is influenced by such factors as existing contribution of livestock to national GDP and percent rural population amongst other factors. Further research is required before accurate forecasts can be made.

In the African Livestock Futures report (Herrero et al. 2014) and Figure 4.2 below show which farming systems are most likely to contribute to future needs for beef, milk and smallstock in Africa. They project that the increase in demand for beef will come from all farming systems with steady growth in the grassland and mixed framing in arid regions, but mostly be filled by major increases in cattle keeping and productivity in the mixed rainfed humid and temperate systems. Cattle milk production will increase exponentially across all systems, but less in the temperate grassland systems. Smallstock meat and milk production will increase massively in the arid grassland and mixed farming systems, and to a lesser extent in the humid grassland and mixed farming system.

Figure 4.2. Contribution of different ruminant livestock production systems to the projected production growth in sub-Saharan Africa to 2050 by SSP scenario

Source: Herrero et al. 2014

Opportunities supporting the industrialization of livestock keeping are likely to be utilized in the future in Africa. These include feed and fodder production, breeding improved varieties and breeds, feedlots and fattening; abattoir and butchery business; dairying and milk processing; restaurants and catering services; meat and milk retail and wholesale; hides and skins processing and value addition; biogas development; livestock and animal product transport and storage.

4.2 Opportunities from mitigation approaches

The IPCC Special Report on Land and Climate Change (2019) estimates that changes in the livestock sector could have a major impact in mitigation and could mitigate 0.12–0.25 GtCO2-eq yr^{-1} at a current carbon prices of USD 20/tonne of carbon. In addition to the technical changes required, the structural changes required in the livestock sector include (i) a major change moving away from consuming ruminant meat towards monogastric meat (pork and poultry); and (ii) find agreement and flexibility to concentrate certain value chain production systems into more efficient regions. Sub-Sahara Africa, China and Latin America were identified as the areas with highest mitigation potential, however achieving these mitigation options would be very difficult to achieve due to "long-established socio-economic, traditional and cultural habits, requiring significant incentives to generate change" (Mbow et al. 2019; p.5). They conclude that "options with large potential for mitigation in livestock systems include better grazing land management, with increased net primary production and soil carbon stock; improved manure management, and higher-quality feed. Reductions in GHG emissions intensity (emissions per unit product) from livestock can support reductions in absolute emissions, provided appropriate governance structures to limit total production are implemented at the same time" (Mbow et al. 2019 p.6).

4.3 Major opportunities for livestock farmers in the Africa sub-continent

Sustainable Development Goals (SDGs)

There are many SDGs where livestock contribute either directly or indirectly, and either positively or negatively, to achieving the SDGs (FAO 2018d; ILRI 2016). Since many of the SDGs are inter-related, improvements achieved under different SDG aims or projects will benefit livestock owners, and assuming that additional funding is made available for projects that address the livestock related SDGs directly, then there is scope for African farmers to benefit, and in doing so improve living conditions or standards for others.

United Nations Commission's Declaration for Combatting Desertification (UNCCD)

The UNCCD (2017) highlights key issues in land and desertification which are particularly relevant to livestock keeping societies in Africa. The report recognizes the vital role African smallholders / farmers play in terms of food production, but also the pressure they are under financially in the face of climate change, the global commodity trade and impact of agribusiness.

Adopting the recommended approaches made above could lead to new markets nationally, regionally and globally; and new investment from the private sector, finance institutions and research organisations (e.g. CGIAR). There are interests in new streams and increased levels of Climate Change Adaptation (CCA) response funding and funding for biodiversity conservation. Climate finance and sequestration funding exists but needs to be studied to find and identify ways to support existing communities, traditional institutions or associations that can positively and constantly show improvements in rangeland and livestock production based on on-site and remote satellite monitoring and sustainable management techniques.

To achieve these opportunities and goals, policy change, enabling environments and supportive institutions are required. Policies that cover all aspects of livestock keeping need to be reviewed to ensure they are cohesive, complementary and supportive to livestock. These same livestock policies need to fit within and complement rather than undermine or oppose other sector policies. Therefore land, environment, climate and agriculture policies, as well as water, health, food safety, trade and energy policies, all need to consider current and future livestock systems. A Nexus approach is recommended.

Just as there is a need for a review of livestock policies, there is also a need to review livestock institutions, and their relevance to current and future livestock systems. There will likely be a change in institutions and their roles. A global thinking is required in the policy design and in terms of future livestock programming.

5. Intervention options to improve livestock management

Various categorisations of adaptation options exist. Thornton and Herrero (2014) group the options into technological, behavioural, managerial, or policy-related interventions that are aimed at increasing resilience, diversification and/or risk management. Woetzel et al. (2020) refer to adaptations that (i) protect people and assets; (ii) build resilience; (iii) reduce exposure; (iv) insure; or (v) finance. The adaptation options listed below are broad and some will be specific to different production systems, as well as socio-economic, cultural and even religious influences.

Migration

Migration of both people and livestock, which has already been an adaption change to climate variability for many centuries. Ayanlade and Ojebisi (2020) noted the increased migration of cattle owners in Nigeria from northern states to the southern states often resulting in increased conflict. Van der Geest et al. (2019) meanwhile reported that migration in West Africa can be either temporary or permanent, and is reflected somewhat in terms of increasing migration to urban areas in recent years and increasing numbers of young people trying to emigrate from Africa to Europe, partly perhaps due to climate change, but also due to some of the non-climate issues such as lack of economic opportunities, political persecution and civil conflict that may have been brought on by climate change.

Despite improvements in mechanization and transport infrastructure across much of Africa, there are increasing concerns that the movement of livestock, particularly to grazing lands, is becoming increasingly difficult due changes in demographics, urbanization, breakdown of traditional institutions and land tenure policies that all pose a threat to mobility. Migration can be restricted to livestock and a few family members, or of the whole herd and family, or of just a few members of the family migrating to find work. Different combinations are found in different farming systems, but migration is more commonly found in the arid and semi-arid grassland and mixed farming systems and is normally standard practice in pastoral and transhumant systems. Concerns have been raised that migration often puts a higher burden on women and women headed households (Van den Bergh-Collier 2007) who remain behind to look after the children and elderly in the highly stressed areas whilst largely the men migrate.

Reducing water consumption and improving water conservation

Reducing water consumption and adoption of irrigation to improve crop farming (van der Geest et al. 2019), which is important in countries where cereals and crop residues are important in the livestock system, as well as ensuring resilience through multiple-income sources (Herrero et al. 2016). Although investments costs of irrigation can be high and a challenge to small-farmers, many farmers are establishing open plastic-lined small-scale water reservoirs on their farms, although the evaporative loss of surface water can be extremely high in ASAL areas, leading to questions in its efficiency as a climate change adaptation.

There are some broad global recommendations that crop and livestock should be produced in systems that require less water or in areas with water abundance (Nardone et al. 2010). Other options based around improving water efficiency include reducing losses (leakage and evaporation); establishment of water networks; improved management of underground aquifers ensuring adequate recharge and judicious extraction; and good governance and enforcement of existing policies and legal frameworks surrounding water issues through the use of water-user associations or equivalent community organisations and institutions.

Integrating and improving on mixed crop-livestock systems

Integrating and improving on mixed crop – livestock systems can also be considered as a form of risk management. There are a number of publications reviewing/promoting the integration of crop and livestock systems as a method of increasing resilience to climate change, with examples from Afar region in Ethiopia (Mekuyie et al. 2018) and Senegal (Brottem and Brooks 2018). Integrating crops and livestock creates a circular economy, largely making better use of feeds and fodder as its core. Some authors have suggested the increased use of synthetic or algae-based proteins as animal feed (IPCC 2018), whilst the considerable increases in re-afforestation projected, if well planned and designed could also provide feed for livestock.

Within mixed crop – livestock farming, there are possibilities of changing to more water efficient and drought tolerant feed and fodder crops (sorghum vs maize or lucerne); water and soil conservation techniques that cushion against rainfall variability and improve yields; and early maturing varieties and planting earlier as seen in Ghana (Antwi-Agyei et al. 2018). Other authors including Thornton and Herrero (2015) and Thornton et al. (2018) warn that mixed farming has some negative impacts or additional requirements, including additional labour requirements and often a higher workload for women, increased capital investment and running costs that may require access to credit, competing uses of crop residues (e.g., feed versus mulching versus carbon sequestration), higher management skills, need for appropriate policies and enabling environment, and better access to markets and establishment of market infrastructure.

Some authors, following profitability studies in Burkina Faso (Antwi-Agyei et al. 2018; Rigolot et al 2017) and in southern Africa (Tibesigwa et al. 2017), note that integrated systems are not without their challenges, and they may not be adaptive in all circumstances. There is need to differentiate between the two options of (i) integrating livestock more into crop systems and (ii) integrating crops more into livestock systems. This will depend on the agro-ecological zones, rainfall variability and projected climate change trends. Encouraging or expanding cropping systems into dry, rainfed ASAL areas could actually increase vulnerability of poor households due the climate variability unless irrigation is available or farmers have enough income or alternative access to finance and credit to cover the shortfalls in dry seasons.

Pasture reseeding and conservation

African drylands are facing degradation in the form of soil fertility declines, loss of biodiversity, soil erosion and more as a result of many drivers, including climate change. Two possible adaptation options are pasture reseeding and conservation. Reseeding programmes can conserve soil to a greater extent than land management and grazing alone by improving vegetation cover and increasing biomass (Mganga et al. 2019).

Pasture conservation can be accomplished through enclosures (Oduor et al. 2018), exclosures (Rossiter et al. 2017) and other management practices like resting periods and reducing stocking rates (DeLonge and Basche 2018). These conservation practices can help water infiltration into soils and improve vegetation cover, resulting in adaptation co-benefits as well.

Early warning, risk management, insurance and new technologies

Improved climate information services combined with strategic investment has been shown to reduce vulnerability of farmers and livestock keepers (Diouf et al. 2019; Hansen et al. 2019), however to be effective the large-scale establishment of weather data gathering stations may be required, especially in Africa where high variability in weather patterns already exists.

Choko et al. (2019) highlight the need for more analysis of climate data to improving early warning systems towards drought and flood in Nigeria. Improved early warning systems and predictive early warning can also help reduce losses from drought, floods or epidemics through preventive action such as fodder storage, offtake or migration. A predictive element is especially required to ensure that the right responses can be put in place before disasters strike. In Kenya, the National Drought Management Authority and FAO have advanced the development of a Predictive Livestock Early Warning System (PLEWS) that particularly looks at forage availability and provides a three- and six-month prediction as to forage conditions in the rangelands (Barrett et al. 2019; Matere et al. 2020).

Index-based livestock insurance has been tried in Kenya and Ethiopia and in Kenya (Chelanga et al. 2017; Takahashi et al. 2016) is being expanded under the government Kenya Livestock Insurance Project (KLIP) funded by World Bank. There are mixed opinions on its value and success and uptake in the early stages has been slow.

Improved market access and off-farm income generation opportunities (though certification schemes, price and credit initiatives) have been proposed by Waha et al. (2018) and the increased use of ICT and digital solutions to reduce transaction costs and improve production efficiencies and financial and market information are recommended (Tesfaye et al. 2019). The use of mobile money (M-pesa) in Kenya has provided a major boost to farmers and markets in remote rural areas.

Most countries suffer from a lack of data regarding numbers, breeds and other data. New technologies and the use of mechanical learning and artificial intelligence in the carrying out livestock census and surveys need to be explored. Electronic chipping is becoming more commonplace, mainly as a herd production tool at farm level, but requires incorporation into a tool to manage herd migration and control stock theft. All of these may require capacity building and better understanding of climate change at all levels from farmer to policy makers.

Diversification

Diversification both within livestock (with shifts to more drought- or heat-tolerant species and breeds such as camels, sheep and goats), or away from only livestock or crops into other livelihoods or mixed crop-livestock systems are recommended (Thornton et al. 2019) especially in sub-Saharan Africa.

Waha et al. (2017), from a study of 18 African countries, showed that the best opportunities for diversification of food and cash crops and livestock occur in areas with 500–1000 mm annual rainfall and 17–22% variability in rainfall; however only 57% of Africa's cropland fulfil these criteria. Countries with high farming diversity potential are humid West Africa, Ethiopia, Burundi, Rwanda and Uganda; whereas East Africa south of Ethiopia, the Sahel, south Africa and the coast of Morocco and Algeria have low potential for crop diversity.

Multi-species herding is an adaptation strategy and enhances resilience (Megersa et al. 2014), and the introduction or adoption of camels as a climate adapted multi-purpose animal is becoming increasingly widespread in parts of east Africa (Kagunyu and Wanjohi 2014; Watson et al. 2016).

Improved hygiene, sanitation, quarantines and movement restrictions

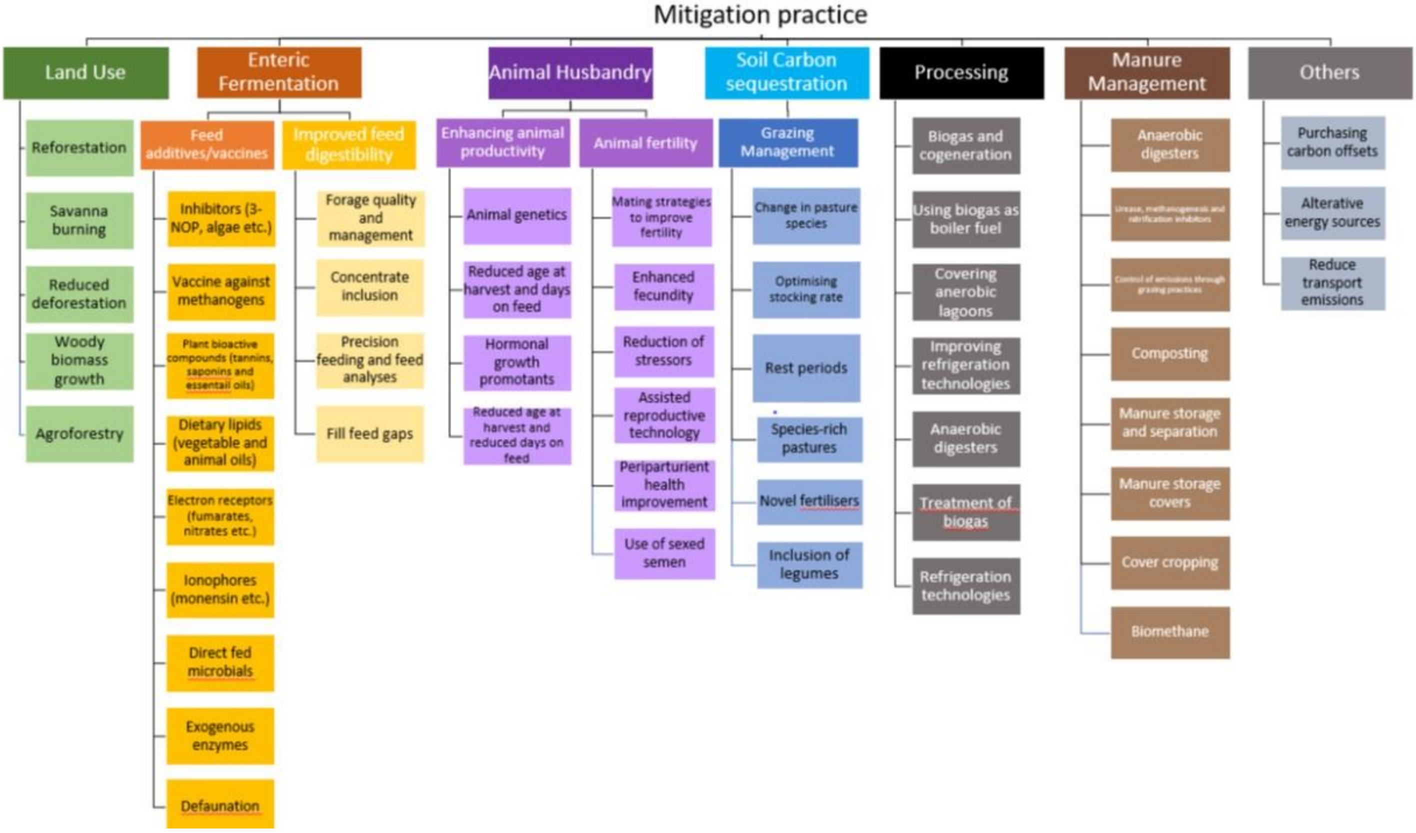
Improved hygiene, sanitation, quarantines and movement restrictions to reduce the spread of disease and vectors will all be required to control the new distribution of existing and new diseases. This can best be done by:

- Capacity building and awareness raising amongst farmers, livestock keepers and local government officials and veterinarians
- Investing more in prevention and control through disease predictions and response scenario planning
- Efficient disease search, outbreak response and rapid reporting using modern tools and technology
- Ensuring good governance and enforcement of laws and guidelines.

5.1 Projected outcomes for adaptation co-benefits

The key mitigation pathways explored in the IPCC reports largely under the heading Carbon Dioxide Removal (CDR) through Agriculture, Forestry, and Other Land Use (AFOLU) are at a higher level than the livestock adaptation pathways with which this report deals, but livestock can indeed contribute to these higher-level mitigation pathways. The diagram below, published in the IPCC (2019) report, summarises possible mitigation interventions in the livestock system.

Figure 5.1. Technical supply-side mitigation practices in the livestock sector



Source: IPCC 2019

Schäfer et al. (2019) note that adaptation alone will not be enough and that livestock owning households will continue to suffer losses, thus the need to go beyond just adaptation in livestock systems but also adapt livelihoods, crop production and look into the adaptation co-benefits of mitigation options such as alley planting, afforestation and re-afforestation.

Many of the approaches listed below can potentially increase carbon sequestration if done in an ordered and planned manner. The World Economic Forum (2020) highlights six land-management practices that all have positive economic co-benefits to farmers and would sequester 1–2

$GtCO_2$equiv annually; they include: (i) planting trees on crop and pasture lands; (ii) maintaining soil structure through minimum tillage, reduced input use and CSA; (iii) cover crops or crop rotations (including fodder or feed crops) in between planting seasons; (iv) planting legumes on pastureland to create a mixed sward; (v) optimizing grazing intensity on pastureland (caution – should be done within the guidelines of the non-equilibrium management approach); (vi) integrating animals into cropland and pasture cropping or mixed farming.

Joint adaptation and mitigation interventions include:

Climate-smart agriculture (CSA) and conservation agriculture (CA)

Climate smart (CSA) and conservation agriculture (CA), and potentially other organic or permaculture agricultural techniques particularly for dry lands are widely documented and training manuals and information platforms available (FAO 2013). The benefits of CSA include: increasing crop yields and incomes and efficiencies with reduced inputs and consequently reduced GHG emissions (Khatri-Chhetri et al. 2017). It should also be noted that the improved water availability and increased crop or vegetative production resulting from CSA and CA in cropping systems also result in improved nutrition, welfare and production of livestock.

Sustainable rangeland management

Sustainable rangeland management can be achieved through planned or deferred grazing, carbon sequestration through increasing above and below ground biomass (Lipper et al. 2010) and improved soil management, changing herd structure and composition. Rojas-Downing et al. (2017) indicate that improved grazing management where stocking rates and carrying capacity are managed, protection and rehabilitation of degraded pastures takes place and rotational grazing is used can increase carbon sequestration. These standard rangeland management terminologies need to be reviewed under a lens of holistic resource management and non-equilibrium grazing systems, which could still provide the same services.

The more modern thinking of holistic resource and grazing management is not based on standard stocking rates and carrying capacities but more on grazing intensity and resting period and offers new methods of implementing sustainable rangeland management in the non-equilibrium conditions common to most of Africa’s rangelands. It has been shown to work well on privately owned or well managed land, however it has proven difficult in many communally owned or managed rangelands in East Africa. Establishing bodies or institutions and supporting the wider understanding of ecosystem health could facilitate its wider uptake and impact.

Rangeland rehabilitation also has joint adaptation and mitigation co-benefits but is often necessary only as a result of the failure of sustainable rangeland management. It includes reseeding, invasive species eradication, erosion control through gabions and bunds, soil enrichment and regular moving of livestock night enclosures, and fencing of enclosures/exclosures to prevent grazing. Rehabilitation tends to be much more costly than rangeland preservation or conservation.

Community conservancies have proven moderately successful in establishing grazing plans and sustainable rangeland management in parts of east Africa; however, they are often disrupted during drought periods when neighbouring communities migrate into the areas and are not informed or unwilling to abide by the grazing laws. Such interventions need to be made on a landscape and territorial scale and plan to include crossing local, national and international borders. The old Pastoral Union system enabled such organization across Sudan, Tchad and Central African Republic and further west into many west African countries.

Biodiversity and ecosystem services

Since most of the extensive grassland grazing and agropastoral systems make use of natural vegetation, where indigenous fauna and flora predominate, there is urgent need to look at livestock and agro-pastoral systems in Africa under a larger biodiversity lens. Boone et al. (2018) recognize the importance of rangelands as providers of ecosystem services, which not only include their use as grazing for livestock, but also for carbon sequestration, water supply, maintenance of biodiversity, cultural or religious significance, recreation and wellbeing. Whilst payment schemes exist for wildlife, water and carbon storage, no schemes exist to compensate pastoralists for the services they provide to others, although emergency destocking schemes during droughts and restocking in recovery phase could be considered as eligible activities for such funding.

Many of the payment schemes mentioned above may not benefit pastoralists due to the nature and rules attached to carbon credits, with the World Initiative for Sustainable Pastoralism (2008) recommending that in future there should be formal markets for other types of ecosystem services—such as carbon sequestration or even provision of clean air and water in pastoralist lands.

Agroecology

Agroecology is an approach to agriculture being promoted as a potential solution for mitigating against climate change. The FAO (2018a, p.1) defines agroecology as "an approach based on applying ecological concepts and principles to agriculture while taking into consideration the social aspects that need to be addressed for sustainable and fair food systems". On livestock specifically, the agroecology approach promotes landscape approaches, improved livestock breeds, crop, agroforestry and livestock integration and recognises the roles of livestock not only in manure provision as organic fertiliser, but also in pruning and weeding (FAO 2018a). The agroecology movement may help in adaptation as it strongly supports local innovation and farmer-to-farmer knowledge sharing and aims to design and use practices that contribute to climate change adaptation and mitigation (FAO 2018a). Interestingly the concept promotes farm consolidation as a means of intensification, rather than sub-division, and this could be interpreted as a form of adaptation that helps build resilience to climate change by increasing the economies of scale and building social capital enabling smallholders to access finance and other safety-nets.

Sustainable intensification, integrated approaches, diets, food loss and livestock transition

There is need for widespread development of integrated approaches. Mpandeli et al. (2018) have analysed the use of the food-water-energy nexus approach in southern Africa, noting that failure to adopt an integrated approach may jeopardize progress towards achieving the SDGs. Combined adaptations have been shown to improve production and profit compared to single adaptation interventions. However, combined and integrated approaches do not just involve high, sector level interventions; they also take place at the farm level.

There is much debate about the need for a reduction of meat consumption and hence demand for animal products, as well as processed foods high in salt and sugar, which would not only reduce GHG emissions but also have co-benefits on health and environment (D'Odorico et al. 2018; Swinburn et al. 2019; Mbow et al. 2019). Indeed, malnutrition and obesity are becoming a growing problem in many countries. Although mostly a problem in developed countries, they are increasingly becoming issues in more developed African countries, especially among urban populations, and interventions to encourage healthier and more environmentally sustainable diets are needed. Options include policies and incentives for better nutrition and diet change and reducing waste and food loss. However, a number of cultural and knowledge issues act as barriers to uptake, especially in Africa.

Nhamo and Muchuru (2019) carried out a literature survey of public health adaptations being carried out in 18 African countries and found that a majority of countries are undertaking awareness-raising on infectious diseases, early warning and disease surveillance. However, very few (Malawi being the main exception) are including awareness on reducing waste or nutritional diet change – highlighting perhaps that these issues are considered more a problem in developed countries than in Africa.

The role of reducing waste and changing to healthier diets is also emphasised when taking up sustainable intensification in the livestock transition, and how circular economies are increasingly important. This echoes the sentiments of Blanchard et al. (2017) regarding the existence of an integrated global food system and increasing inter-dependencies. With the 'new' thinking on meat in global diets, the future of the livestock sector is even less clear than that of the crop sector (Thornton 2010). Although diet and food waste are more of middle- and upper-income human education problems than a livestock problem, addressing it through education and awareness raising across continents and generations will have significant benefits.

Reducing methane emissions

The main emissions from livestock are from enteric fermentation, and supplementing the diet with high energy concentrates containing cereal grains and oil meals reduces methane emissions (Dourmad et al. 2008; Rojas-Downing et al. 2017). Methods to reduce enteric methane emissions include providing higher quality forage, increasing protein and dietary fat, as well as the use of hormone and antibiotic supplements and anti-methanogens (Rojas-Downing et al. 2017); however, it should be noted that the effects have been found to be short-lived and may be considered controversial, unethical or risky especially regarding anti-microbial resistance; whilst increased production of cereals and oil meals to be used as improved animal feeds can result in a significant increase in GHG emissions through expansion of agriculture and destruction of forests. The approach of using of cereals and other crops that can be eaten or otherwise used directly by mankind is questionable, as it may be better or more nutritionally efficient to use these foods to address human nutrition directly rather than pass them through a second entity in order to produce more protein either as meat or milk.

Policy change and enabling environments, and improved coordination and governance

It is widely acknowledged that in many African countries data and information on livestock numbers, production and distribution is lacking or incomplete, as most population figures are estimates based on old census data. Such lack of information undermines the current call for evidence-based policy making. One solution would be for every country to develop livestock master plans, which include data and information generation. Such exercises carried out in Rwanda and Ethiopia have had major impact in terms of attracting, and returns on, investment.

Niles and Brown (2017) research in 12 African counties again reiterates that single solutions will not be effective, and policies and response frameworks need to identify the best options for each ecosystem, and the importance of involving local communities in policy formulation and response.

Market opportunities and diversification

Exploiting market opportunities and diversification within livestock is closely linked to intensification. Ouédraogo et al. (2017) note that market infrastructure in many LDICs is critical for successful operation of mixed crop-livestock systems. Encouraging a business sense to livestock keeping would improve marketing, but is a long-term commitment.

Diversification can be achieved at two levels: (i) within livestock, or (ii) moving out of livestock (and indeed agriculture more broadly). There has already been a move in some east African countries from cattle to smallstock and camels which are more drought tolerant, browsers rather than grazers, and consume less water per kg liveweight than cattle. The paradox, however, is that globally the recommendations are to reduce emission intensity through more productive livestock in more intensive systems, however the trend in Africa has been towards more hardy breeds and species more adapted to climate variability.

Waha et al. (2017), from a study of 18 African countries, found that at a household scale, more farming diversity resulted in greater success in meeting their consumption needs, but there were limits and conditions that made this so, especially the ability to have off-farm income to help purchase food; to have a market orientation in production; owning livestock; having a family member with non-agricultural employment; and having sufficient land access/ownership. As noted earlier, in Africa as a whole, opportunities for diversification within agriculture restricted to areas where there is 500–1,000 mm annual rainfall and low (17%–22%) rainfall variability, which only occurs in 56% of African cropland areas. Policies must therefore only consider agricultural diversification as a priority in certain areas that fit the above parameters.

Diversification and moving out of farming and agriculture, as has been seen in many African countries, is not always successful. In South Africa, where many people left farming and livestock keeping as the government policy and support was not favourable, still has very high poverty rates despite leaving agriculture (Shackleton et al. 2014).

5.2 Gender, age and cultural constraints to adaptation responses

It has already been recorded how climate change affects different members of the population or household differently, with women, children, the elderly and people living with disability often the worst affected. Many studies have listed age, gender and head of household as affecting vulnerability and that female-headed households are more vulnerable to climate change impacts than male-headed households (Jost et al. 2016; Flatø et al. 2017). Adapting to climate change also has its costs and challenges that also affect these different populations, making it even harder for them to adapt.

Different adaptive practices exist within different genders according to gender roles in livestock management, ownership and rights (Rao et al. 2019; Omolo and Mafongoya 2019). Women may have more (Wangui 2014) or less (Aregu et al. 2016) access and role in management of pastures depending on culture and land tenure system. Whilst adopting livestock into a mixed farming system may reduce vulnerability of women to climate change, it does not always lead to improved nutrition in women and children (Nyantakyi-Frimpong and Bezner-Kerr 2015; Dumas et al. 2018). Securing women's rights, as compared to provision or uptake of technology, may itself contribute significantly in impacting on climate resilience and adaptation.

In Malawi, Chingala et al. (2017) reported access to animal feed, animal health and water resources for beef producers in a mixed crop-livestock system varied significantly between genders and age groups. Ngigi et al. (2017) found that women in Kenya were more likely to be involved in adaptation actions related to crops, whilst men continued to be more involved in livestock adaptation.

Tavenner et al. (2018), also found in Kenya that although women prefer to sell through both formal and informal markets, many were often selling milk in the informal market as the income, although small, was under their control, whereas payments through the formal sector were often paid to the husband. She found “women were responsible for most management tasks around dairy animal husbandry, including fodder and water provisioning, veterinary health, manure removal, and milking” (p.1) and that “only 10-15% of married women report deliberate joint financial and labour planning with husbands” (p.2).

6. Weakness and threats to adaptation in livestock management systems

Adoption of climate adaptation responses in Africa is not automatic. Adoption rates have been shown to be as low as 30% over two decades (Thornton et al. 2018). There are many constraints to adoption; some due to gaps in terms of knowledge, and others due to a series of blocks or barriers.

6.1 Knowledge gaps and questions

Rojas-Downing et al. (2017) documented a list of twelve knowledge gaps, and this has been adapted and added to from the literature review. The most important knowledge gaps surrounding livestock and climate change are:

1. Many studies have been carried out at continental or regional level; there is a need for more local level studies.
2. Most research is on cattle; knowledge gaps exist around non-ruminants (poultry and pigs) and other emerging livestock such as camels and insects.
3. There has been very little research on water availability for livestock production under climate change
4. More research is needed on the nutritional and metabolic processes of livestock in a changing environment.
5. There is need to identify the breeds with the best adaptive capacities to climate change.
6. There are major gaps in data and information on animal numbers.
7. There are still gaps around knowledge on livestock diseases and the interaction with climate change (Cable et al. 2017; Hristov et al. 2018).
8. More is needed on understanding local as well and indigenous knowledge and coping strategies and measuring how successful local and existing adaptation responses are compared to introducing new technologies (see Box 6.1 below).

9. More knowledge is needed on the cost-effectiveness and scalability of various adaptation options, especially on the macro-economic viability of community-based adaptation (CbA) and biodiversity management
10. More knowledge is needed on risk mitigation and the potential of biodiversity management

Enahoro et al. (2019) highlight the need for more research on: (i) closing the yield gap in African livestock, thus reducing the need for increasing the herd size and reducing the GHG emissions and pressure on water and environment; and (ii) improved accounting of animal feeds in terms of source and use, allowing better estimations of GHG emissions mitigation.

Since livestock owners have been keeping different domesticated animal species in Africa for several millennia, there is a lot of indigenous knowledge already within the societies (see Box 6.1), however much of it may not have been documented and is at risk of loss over time (Mapfumo et al. 2016; Makondo and Thomas 2018; Kaya and Koitsiwe 2016).

It is clear that there are initiatives and calls to reduce livestock numbers, meat consumption and demand; but it is unclear just how this might affect producers, especially in Africa. Many African farmers are not commercially oriented and the sole purpose of livestock is not just the mass production of marketable milk and beef, but the keeping of animals is multi-purpose, culturally significant and an asset base for covering emergencies as well as living expenses.

Box 6.1. Indigenous knowledge on climate change

Many of those affected by climate change in Africa have been living and coping with high variation in rainfall for centuries, and the livelihood systems such as slash and burn and mobile or nomadic pastoralism have evolved as a result. Local and indigenous knowledge levels are high but often overlooked in favour of "modern or external" responses or management systems. Kijazi et al. (2013) have documented examples of communities in Tanzania using indigenous knowledge in climate and weather predictions for drought, flood, pests and diseases and taking appropriate adaptive actions.

Many indigenous adaptive mechanisms already exist and have been documented in Africa (Gautier et al. 2016; Sultan and Gaetani 2016; Zougmoré et al. 2016; Traore et al. 2015; Sanogo et al. 2017), from mobility and migration to sharing and reciprocity (Omolo and Mafongoya 2019) across most of the continent. Some studies show strong correlation between indigenous perceptions of climate change and meteorological data, but in some areas the links are less aligned. Whilst many farmers have knowledge of climate change simply because they are experiencing it, there may well be a gap in understanding what the future prospects are in a warming world and there is a need to really understand what are the real drivers of change. Indigenous African peoples have much knowledge and capacity for dealing with climate variability, however access to finance and capacity to invest in the required technology and responses may be out of reach for many small farmers and livestock keepers.

On the subject of reducing meat intake as a major mitigation mechanism, the experiences, impact and lessons learned from similar initiatives to control intake and production of other products, such as sugar and sugary beverages, should be studied and compared to potential impact (good or bad) in the livestock sector. Research is needed to determine whether a similar approach or system might possibly be used to benefit livestock producers in developing countries, where a "green label" could be established to promote environmentally conscious livestock products reaching the international market.

6.2 Barriers and challenges to adoption of climate change adaptation interventions

Different authors approach the subject of why climate change response is not taking place so rapidly in different ways. Many identify the challenges involved, but most of the recent debate and terminology used is around identifying the barriers and enablers of change. Others write of drivers, triggers and stressors.

In Africa, poverty and lack of capacity to invest in CSA or climate change adaptation; high dependency on climate dependent livelihoods; unemployment; lack of social support; low education levels; gender inequalities; high levels of HIV and poor health services have all been listed as constraints or challenges to adapting to climate change (ASSAR 2015). Other barriers and enablers to adaptation are finance (Shackleton et al. 2015; Castells-Quintana et al. 2018), technology (McNamara and Buggy 2017), skills, institutional capacity (Oberlack 2017), governance (Sidibé et al. 2018) and culture. Cultural issues are specifically referred to as shared characteristics such as worldviews, values, norms, taboos and behaviours that are often institutionalised within structures related to social status, caste and gender. Including social status, caste and gender as cultural factors emphasises the very pivotal role cultural factors and deep-rooted traditions may have on shaping development, uptake, and effectiveness of adaptation actions in Africa.

At the farm level, Thornton et al. (2016) have identified and ranked the constraints to the different climate change adaptation options on smallholder mixed crop livestock systems in sub-Saharan Africa. The constraints include investment costs, input and operating costs, risk, access to technology, technological know-how, temporal trade-offs, CSA trade-offs, information, acceptability, and the state of the evidence base. ASSAR (2019) also note that multiple barriers combine to reduce adaptation, but they are dynamic and over time barriers can turn into enablers.

The role of traditional and modern institutions in current day livestock production may also be a factor in the rate of adaptation, as they may have different agendas and roles to play and operate at different speeds. A large proportion of the livestock keeping population in Africa manage animals in a traditional manner according to customary rules and laws and may not be aligned to the current thinking on climate change.

Challenges are also seen in terms of scaling-up. Whilst livestock keepers in the tropics have already adopted adaptive responses to climate change, especially through migration, increased diversification and off-farm sources of income and other management practices (Thornton et al. 2018), Vermeulen et al. (2018) argue that many of the investments to date have not proven transformative on a large scale and noted that although many more climate change projects are funded in Africa, many of these initiatives were not resulting in adaptation action that has significant impact. In Australia, the use of participatory approaches and planning helped stakeholders and farmers better understand the complexities and difficulties of climate change and jointly build strategies to prepare and adapt (Puig et al. 2011).

Before deciding on any one approach or solution, one must look at inequalities that might exist and might be the drivers for food insecurity and malnutrition. Different groups may be affected in different ways. For example, lobbying to move away from meat in diets may be good for food secure but malnourished groups in the west or in urban areas, but could be detrimental to children and women of reproductive age, low-income consumers, small-scale producers, forest-dependent communities and others including the livestock industry actors in less developed countries.

7. Conclusions and recommendations

7.1 Conclusions

The possible futures of livestock keeping in Africa are many given the many changes underway on the continent and globally. Climate change is a current reality in Africa. Temperatures are increasing faster than on other continents, but with different effects being experienced in different African regions. There is increased drying in southern and western Africa and greening in eastern Africa. Increasing variability in rainfall and weather patterns is just as much a threat as climate change itself. Climate adaptation responses are urgently required. The higher the temperatures rise, the greater the impact and the higher the costs of adaptation. Mitigation analysis and interventions are also required in Africa. Integrated and inter-sectoral planning and responses are required.

Cross border and inter-sectoral (crops, livestock, water, food security, livelihoods, energy, etc.) coordination that can improve resource flows and tackle issues at landscape and territorial scales are recommended. The nexus approach, incorporating water, energy, and food and nutrition security within a climate change lens, can achieve this and break down the silos that often exist between different ministries and administrative units. Due to the multi-level effects of climate change and its responses, policies and strategies must also be cross-sectoral and holistic, including ecological and environmental issues as well as economic and humanitarian issues.

To improve adaptation among African livestock keepers, the use of technology and smart farming techniques, feed inventories and early warning systems can help. Better grazing management and maintaining soil cover in agricultural fields through CSA will also improve water penetration and reduced water loss through run-off and evaporation. Other adaptation options suited for extensive mixed systems include changing livestock species, improved feeding, grazing management, altering integration between crops and livestock, food storage, and weather information. In intensive mixed systems, changing crop varieties can also be appropriate, along with changing livestock breeds, and improved feeding. Although diversification into other animal breeds is a potential adaptation response, this may face cultural constraints and require capacity support in terms of training. Cross-breeding coupled with diet intensification has been shown to provide substantial efficiency gains in livestock production and methane output.

Animal product storage and preparation not only protects households from seasonal food insecurity and changing weather patterns but can reduce losses and GHG emission intensity of production through increasing food availability at the household level and reducing production-related emissions. In addition, storage and processing generates additional value and alternative income from selling in the market. There is large scope for improving the quality and preparation of hides, skins and leather in Africa, to increase incomes and resilience to climate variability.

Specific recommendations for different value chains and regions can be used to guide different interventions in different farming systems and agro-ecological zones in Africa. East and West Africa have the highest potential for growth in milk production, while West Africa shows the highest potential for growth in production of monogastrics. East Africa has potential for improving production of ruminant meat. Pastoral systems in all areas have the potential to increase production both meat and milk. When looking at the trends of demand for livestock products, expansion of cropland and grassland will be required in the future to meet population needs. Intensifying production on existing land can help avoid encroaching on forests.

7.2 Recommendations

- Generate evidence to fill knowledge gaps on potential options for diversification, bio-physical and socio-economic aspects of livestock production systems, and the future of livestock pests and disease under climate change
- Promote CSA, water harvesting and storage, natural resource management, re-afforestation, fodder and feed production, and farmer field schools
- Identify policy and finance barriers and enablers to livestock sector development and act upon them.
- Promote improved breeding but only in combination with improved feeding and fodder production and supplementation
- Design and update national animal feed strategic plans and strategic feed reserves; support predictive livestock early warning systems and early warning–early action approaches; establish feed inventories and feed stores; promote the establishment of inter-community landscape level grazing plans and natural resource management plans at community and farmer level
- Re-examine carbon sequestration market standards and update requirements for soil carbon projects to make them more accessible to African small farmers in extensive grazing systems

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