CHAPTER 14

Adaptive Livestock Production Models for Rural Livelihoods Transformation

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14.1 INTRODUCTION

Livestock is an integral part of the principal agricultural systems in southern Africa. The future role and populations of livestock will change depending largely on climate but equally important the human population and the resource use and availability for agriculture (Alexandratos and Bruinsma, 2012; Douxchamps et al., 2016; Thornton, 2010). Climate change will affect rainfall and temperature, which in turn will affect feed production and supply of livestock products to markets. As crop–livestock systems evolve in southern Africa, suitable and innovative technologies will be required to further develop livestock systems. Similarly, policies on livestock protection, genetics and breeding, health and

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nutrition will be required (Thornton, 2010). The development of climate smart technologies and policies feed directly into benefits that may accrue to smallholder farmers who rely on livestock for food and income. Climate-smart livestock production basically involves adaptation through the use of technologies that increase resilience of production and feed-base systems in a sustainable way (FAO, 2013), for example, increasing livestock productivity at minimal greenhouse gas (GHG) emission. Management of rangelands becomes important because they act as carbon sinks. The development of feed banks can be encouraged as this allows the rangeland opportunities to recover and evens out the supply of better quality feed across seasons. Improved quality of feed reduces emission of GHGs from livestock enterprises.

The greater part of planet land is suitable for livestock production. World over, livestock production seems to be decreasing except for sub-Saharan Africa (Table 14.1). Of course, figures often differ by country because of different policies, for instance, in Zimbabwe, agriculture is targeted for 12.5% growth in 2018 compared to −1.3% in 2013 with

Table 14.1 Annual livestock production growth (percent p.a.)

	1961–2007	1987–2007	1997–2007	2005/2007–30	2030–50
World	2.2	2.0	2.0	1.4	0.9
Developing countries	4.3	4.5	3.4	2.0	1.3
Idem, excl. China and India	3.4	3.6	3.5	2.1	1.5
Sub-Saharan Africa	2.5	2.8	3.3	2.7	2.6
Latin America and the Caribbean	3.2	3.8	3.8	1.6	0.9
Near east/north Africa	3.3	3.3	3.0	2.2	1.7
South Asia	3.7	3.6	3.2	2.7	2.2
East Asia	6.5	5.9	3.4	1.8	0.8
Developed countries	1.0	−0.1	0.6	0.6	0.2
Forty-four countries with over 2700 kcal/person/day in 2005/2007[a]	2.7	2.9	1.8	1.1	0.5

Aggregate livestock production was derived by weighting the four meats, milk products, and eggs at 2004/2006 international commodity prices.

[a]Accounting for 57% of the world population in 2005/2007.

Based on Alexandratos, N., Bruinsma, J., 2012. World Agriculture towards 2030/2050: The 2012 Revision, (ESA working paper).

livestock contributing more than 40% of this growth. Drought conditions and rainfall variability are set to increase in sub-Saharan Africa due to climate change, making rainfed crop production system more vulnerable relative to the more resilient livestock production system. As a result, livestock will become increasingly important in making a contribution to livelihoods of farm families. However, most of the livestock are found within the smallholder farming sector where the production objective is often risk management.

14.1.1 Mindsets Have to Shift Toward Commercialization

In smallholder farming systems, livestock are reared on grassvelds, browse, and nongrain crop remains from maize, millet, rice, and sorghum crops, and hay. Livestock contributes manure and traction power toward crop production. Livestock acts as a form of insurance against crisis times and supplies farmers with a source of regular income from sales of milk, eggs, and other products (Swanepoel et al., 2010). Therefore, the livestock production business is conducted for a range of values: as a form of wealth, prestige, or business.

Livestock should contribute more to people's livelihoods and nations' gross domestic product. Farming for subsistence and risk management have several disadvantages. Livestock numbers become difficult to control if risk management remains the main objective. With the climate changing toward drier conditions, greater proportions of livestock will be held for risk cover. Also, people tend to adjust for loss in crop production by investing more in livestock. Large numbers would present some sense of security and pride. However, increasing livestock numbers in the face of climate change oriented toward reduced feed base can lead to poor livestock productivity, lower meat yield and quality, poor health, increased vulnerability of rangelands to uncontrolled stocking rates, and reduced livelihoods due to reduced feed-base, increased disease outbreaks, and increased livestock deaths. Intensification (Fig. 14.1) requires commercial feeds that can be out of reach of most smallholder farmers because of high costs. This scenario promotes the mindset of keeping livestock for risk aversion and will forever keep off-take from the smallholder farming sector at its lowest. Sub-Saharan Africa cannot develop as anticipated when the major resource is not being mobilized to generate income and employment. The major question therefore is, "How can livestock in smallholder sector be mobilized for local households to generate income to diversify of their livelihoods?" What is needed for people to commercialize their livestock? Who should commercialize what?

Figure 14.1 Pictures of livestock farms in southeastern Zimbabwe where both improved breeds of cattle and goats are produced. *Photos by Chrispen Murungweni.*

Livestock plays key sociocultural roles within rural communities. Livestock development projects targeted for improving rural livelihoods through commercialization should take sociocultural roles of livestock into consideration. In addition to complex ownership patterns, low productivity is a major challenge for the majority of livestock households. Uncoordinated planning for marketing results in low off-take, poor marketing networks, under developed marketing infrastructure, and poor access to livestock markets. Such conditions are detrimental to the development of the livestock industry; the starting point should be giving confidence to the farmer that their breeding stock is safe under different climatic conditions for them to feel secure even when selling periodically. This is possible if the famers are knowledgeable about advantages of increasing productivity over increasing numbers, if they can understand importance of self-organization and consistency and persistence of supply line of quality product over crisis disposal of poor quality materials.

14.2 LIVESTOCK MANAGEMENT IN A CLIMATE-SMART AGRICULTURAL ENVIRONMENT

The strategies used by farmer in livestock production largely depend on the resources available and the level of development of the livestock value chains. Climate plays a crucial role in the definition of the livestock systems applicable in each location. Table 14.2 shows some of the systems that are applicable across a range of environments.

Climate change can be expected to have several impacts on feed crops and grazing systems, including the following (Hopkins and Del Prado, 2007):

Table 14.2 Livestock systems according to the classification of Seré and Steinfeld (1996)

Generic	Specific	System
LG (livestock only)	LGA	Livestock only systems, arid–semiarid (LGP <180 days)
	LGH	Livestock only systems, humid–subhumid (LGP <180 days)
	LGT	Livestock only systems, highland/temperate[a]
MR (mixed rainfed)	MRA	Mixed rainfed crop/livestock systems, arid–semiarid (LGP <180 days)
	MRH	Mixed rainfed crop/livestock systems, humid–subhumid (LGP <180 days)
	MRT	Mixed rainfed crop/livestock systems, highland/temperate[a]
MI (mixed irrigated)	MIA	Mixed irrigated crop/livestock systems, arid–semiarid (LGP <180 days)
	MIH	Mixed irrigated crop/livestock systems, humid–subhumid (LGP <180 days)
	MIT	Mixed irrigated crop/livestock systems, highland/temperate[a]
LL (landless)	LLM	Landless monogastric systems
	LLR	Landless ruminant systems

[a]Temperate regions: areas with one or more months with monthly mean temperature, corrected to sea level, of less than 5°C. Tropical highlands: areas with a daily mean temperature, during the growing period of 5–20°C.

- Changes in herbage growth brought about by changes in atmospheric CO_2 concentrations and temperature;
- Changes in the composition of pastures, such as changes in the ratio of grasses to legumes;
- Changes in herbage quality, with changing concentrations of water-soluble carbohydrates and N at given dry matter (DM) yields;
- Greater incidences of drought, which may offset any DM yield increases;
- Greater intensity of rainfall, which may increase N leaching in certain systems.

14.2.1 Livestock–Crop Interactions

In southern Africa crop–livestock farming systems are dominant over other farming systems (Mcintire et al., 2016). Under this system, land use is a characterized area under annual and perennial crops and area reserved for livestock. Compared to the large-scale sector, the allocation of land resources is not demarcated such that during off-season for crops livestock graze crops remain on the fields. Livestock manure and provision of draught power are the major linkages between the crops and the livestock sections of agricultural production. Manure, in particular, is a key resource that links the nutrient cycles on the grass veld and on the cropping fields (Herrero et al., 2015; Mcintire et al., 2016). Yet it is widely known that GHG emissions from manure constitute about 40% of methane, a significant amount of the total emissions from agriculture systems (Herrero et al., 2013). Climate extremes threaten the productivity of both cropping and grassland on the one hand, whereas livestock manure production and management exacerbate the occurrence of extremes. Sustainable crop livestock systems require both mitigation and adaptation practices to maintain production for an increasing population.

14.2.2 Manure as a Key Resource in Crop–Livestock Systems

Manure use as a soil fertility input for smallholder farmers has been documented by numerous researchers (Mugwira and Murwira, 1997; Murwira et al., 1995; Nhamo et al., 2003; Nyamangara et al., 2003). The overall effect of manure on crop production has been explained by the intrinsic quality characteristic of the manure as influenced by the livestock systems, management, curing, and storage (Nhamo et al., 2003). Major benefits from manure have been as a result of the contribution to the nitrogen (N) economy on cropping systems (Mugwira and Mukurumbira, 1984; Nyamangara et al., 2003). High-quality manure from dairy feedlots has shown the potential use in a substitutive manner with mineral fertilizer sources (Nhamo, 2011). Fig. 14.2 shows that when high-quality manure is used in combination with mineral fertilizer the overall fertilizer-use efficiency was relatively comparable across the combination applied on maize. The use of manure needs to be carefully reviewed in view of its contribution to methane production and potential environmental pollution, especially where large herds of livestock are involved.

14.2.3 Manure Emissions and Pollution

Livestock produces significant amounts of methane, a GHG that contributes to climate variability. Enteric fermentation and animal wastes contribute about 80 and 25 million tons respectively of methane (total 105 million tons) annually, making them the major source of emission from agriculture (Moss et al., 2000). Several factors determine the amount of CH_4 production in the livestock systems. Factors such as level of feed intake, type of carbohydrates in the diet, feed processing, and alterations in the ruminal

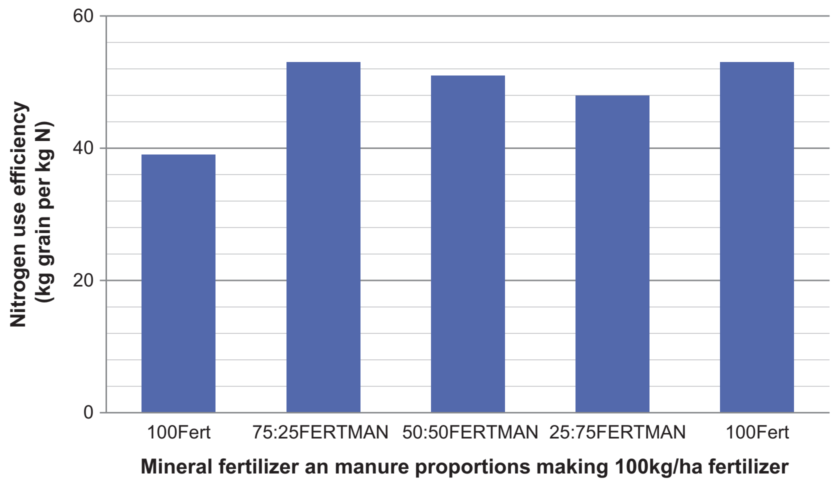

Figure 14.2 Nitrogen use efficiencies of high-quality dairy feedlot cattle manure and mineral fertilizers on maize in Zimbabwe.

microflora (Johnson and Johnson, 1995). Manipulation of these factors can reduce methane emissions from cattle. Slurries are also a significant source of NH_3 and N_2O emissions to the atmosphere (Amon et al., 2006). Dominant emissions of methane occur during storage, whereas nitrous oxide emissions largely occur during field application of manures. Several methods have been put forward to reduce and/mitigate GHG emissions, which include the use of organic material that acts as absorbent in manure slurries.

High-quality manure when not disposed of properly can cause pollution. The high N and P content in the manure either leaches into soil profiles or washes away into water bodies where they cause eutrophication. Therefore, there is a need for proper management of feedlot heaps of manure besides the GHG emissions.

14.2.3.1 Management of (In)breeding in Livestock Production Systems

Breeding is a very important driving force in adaptation to future production conditions. Breeding has made large contributions to improved efficiency and thus indirectly progressing to smart climate agriculture. None the less, there is little evidence that animal breeding organizations have considered climate change adaptation in their definition of breeding objectives and breeding schemes. Inbreeding is technically defined as the mating of animals more closely related than the average relationship within the breed or population concerned. It is the increase in the probability that an offspring receives the same gene from both parents. In general, inbreeding results in an overall lowering in performance. It is most obviously reflected in poorer reproductive efficiency, including higher mortality rates, lower growth rates, and a higher frequency of hereditary defects. Despite these generally harmful effects, inbreeding is a very useful tool in the field of animal agriculture. It enables the breeder to uncover and eliminate harmful recessive genes within the population, thus making the livestock more adaptable to the prevailing climatic conditions. It is also essential to the development of prepotent animals and is desirable in the development of distinct family lines. In addition, seed stock and commercial producers have successfully used line breeding to maintain a degree of genetic relationship in their animals to some outstanding ancestor or ancestors.

The decrease in fitness that results from such inbreeding is known as *inbreeding depression*. Inbreeding depression is thought to be caused primarily by the collection of a multitude of deleterious mutations, few of them fatal, but all with diminishing fitness. Normally, in an out-breeding population these alleles would be selected against, hidden, or corrected by the presence of good alleles in the population. This explains why we do not all have many genetic diseases as sexual reproduction and shuffling of alleles of genes occurs when two unrelated individuals mate. Inbreeding depression encompasses a wide variety of physical and health defects that warrants careful management in achieving smart climate agriculture. Any given inbred animal generally has many defects including elevated incidence of recessive genetic diseases, reduced fertility both in litter size and in sperm viability, increased congenital defects such as cryptorchidism, heart defects and cleft palates, fluctuating asymmetry (such as crooked faces, uneven eye placement and size), lower birth weight, higher neonatal mortality, slower growth rate, smaller adult size, and loss of immune system function.

Livestock production contributes to climate change through GHG emissions especially of methane gas by ruminants. GHGs are often blamed for increasing environmental temperatures. Livestock is, however, affected by climate change through the physiological effects of higher temperatures on individual animals; as a result, geographically restricted rare breed populations will be badly affected. Indirect effects may be felt via ecosystem changes that alter the distribution of animal diseases or affect the supply of feed. In sub-Saharan Africa where climate change models predict increased temperatures due to climate change, breeding goals need to be adjusted to account for higher temperatures, lower quality diets, and greater disease challenges. Species and breeds that are well adapted to such conditions may become more widely used. Climate change mitigation strategies, in combination with ever increasing demand for food, may also have an impact on breed and species utilization, driving a shift toward monogastrics and breeds that are efficient converters of feed into meat, milk, and eggs. This may lead to the neglect of the adaptation potential of local breeds in developing countries. Given the potential for significant future changes in production conditions and in the objectives of livestock production, it is essential that the value provided by animal genetic diversity is secured. This calls for better characterization of breeds, production environments, and associated knowledge including the compilation of more complete breed inventories, improved mechanisms to monitor and respond to threats to genetic diversity, more effective in situ and ex situ conservation measures, genetic improvement programs targeting adaptive traits in high-output, and performance traits in locally adapted breeds, increased support for developing countries in their management of animal genetic resources, and wider access to genetic resources and associated knowledge.

A practical approach for minimizing inbreeding and maximizing genetic gain is practiced in dairy cattle where the best bull is selected for each cow. This is based on the offspring estimated breeding values minus inbreeding (F) depression to reduce the average inbreeding of the calves by about a third to half even when the cost of inbreeding depression is as low as 3%.

In controlling inbreeding in modern livestock breeding programs, accurate breeding value estimation, and advanced reproductive technologies are of paramount importance. Such programs lead to rapid genetic progress and accumulation of inbreeding through more impact on a few selected individuals or families. Inbreeding rates are accelerating in most species, and economic losses due to inbreeding depression in production, growth, health, and fertility are a serious concern. Most research has focused on preservation of rare breeds or maintenance of genetic diversity within closed nucleus breeding schemes. However, the apparently large population size of many livestock breeds is misleading because inbreeding is primarily a function of selection intensity. Corrective mating programs are widely used in some species, and these can be modified to consider selection for economic merit adjusted for inbreeding depression. Selection of parents of artificial insemination bulls based on optimal genetic contributions to future generations, which are a function of estimated breeding values and genetic relationships between selected individuals, appears most promising. Rapid implementation of such procedures is necessary to avoid further reductions in effective population size.

Fortunately, most breeders are well aware of the negative effects of severe inbreeding, and few breeders would purposefully breed siblings with one another. However, another strategy, sometimes called line breeding, is very common, and is practiced. Line breeding involves mating within a historically defined and related set of individuals (a line). Lines may be formally or informally recognized and there may be lines within lines. Within these family lines, some people may maintain or promote even smaller lines. These lines are maintained because each line has (or is perceived to have) unique and desirable traits, e.g., disease resistance. However, the degree of inbreeding is related not just to the immediate relationship between the two mated individuals but also to the degree to which these individuals were already inbred. For instance, if a particular bull is widely used in a line-breeding program, then many of the cattle in that program will already share the genes of that bull and the chances of getting two deleterious alleles from that bull in the same offspring are greatly increased. Even small increases in inbreeding result in some inbreeding depression. For instance, just a 1% increase in inbreeding results in a measurable decrease in milk quantity and quality, shortening of productive life, and increase in calving interval in studied breeds of cattle.

The effects of inbreeding can also be avoided to achieve climate smart agriculture. When two lines are crossed, then any deleterious alleles present in one line but not in the other are masked, and there is typically a boost in the fitness of the offspring. This effect is known as heterosis or hybrid vigor and is essentially the opposite of inbreeding. This effect even extends to crosses between breeds of cattle, which is why cross-breeding programs are popular. Reproductive technologies currently available allow high selection intensity in most livestock species and are combined with selection methods, which take into account family information, such as best linear unbiased prediction. As a result, response to selection has been enhanced but rates of inbreeding have also increased and they currently represent a serious concern for several breeding programs due to the possible consequences in terms of inbreeding depression and genetic variability. Therefore, methods have been proposed where selection is carried out by appropriately weighing the predicted breeding value of an individual and the inbreeding generated in the population. Pure breeders and line breeders use inbreeding to select for a trait, which they seek to promote. As the relatedness (homozygosity) increases due to inbreeding some deleterious recessive traits begin to manifest in your herd, for example, inbreeding severely reduces milk yields over time as the homozygosity of the livestock increases. In beef production, important production traits such as conformation, weaning weights, weaning age, age at first calving, and postweaning gains are all affected by inbreeding.

14.2.3.2 Development of Livestock Markets Under Fragmented Livestock Marketing Environments

The potential of the largest proportion of farmers to commercialize livestock lies on small stock. Almost every household in sub-Saharan Africa owns some form of poultry, a bigger proportion keep small stock (to include small ruminants) and cattle. It is difficult to involve farmers in formal marketing if the farmers are not organized enough to develop sustainable marketing channels. Farmers keep different types of livestock for various diverse reasons: prestige, risk aversion, drought power, food, butter exchange, etc. The numbers are also diverse per individual household. Making a typology of households is the first most important start to develop a viable marketing value chain. Typology facilitates the correct targeting with interventions for vibrant innovation within communities. If farmers organize themselves and their system in a way as proposed in Fig. 14.3 below, commercialization of livestock can be possible. This model seeks to develop an organized breeding and conservation, product processing, and marketing system for livestock by farmers themselves.

Typical of the economies of most developing countries, the noncommercial smallholder farmers use an informal or spot on marketing system, which is more often than not, a system of necessity than a system of choice. Informal markets hold potentially many risks to both the producer and the consumer, whereas commercializing and formalizing the production and marketing of livestock in the smallholder areas will require a vast outlay of capital resources, but gains on infrastructure, institutions, legal frameworks, markets, novelty in product development, capacity building, and technology transfer will empower these people. The proposed model (Fig. 14.3) aims at promoting a shift from subsistence activities that are commonly a characteristic of rural households, especially the poor, to a focus on a business venture that has the potential to generate enough income to improve rural livelihoods.

Most rural farmers keep small herd sizes of livestock ranging from 1 to 20 in large stock and one to over a 100 for small stock. Small numbers result in high transaction costs for the smallholder livestock producers to enter the commercial market. The proposed business venture (Fig. 14.3) has a special characteristic of pulling resources together by participating households. It encourages networking within farmer groups and between farmers and

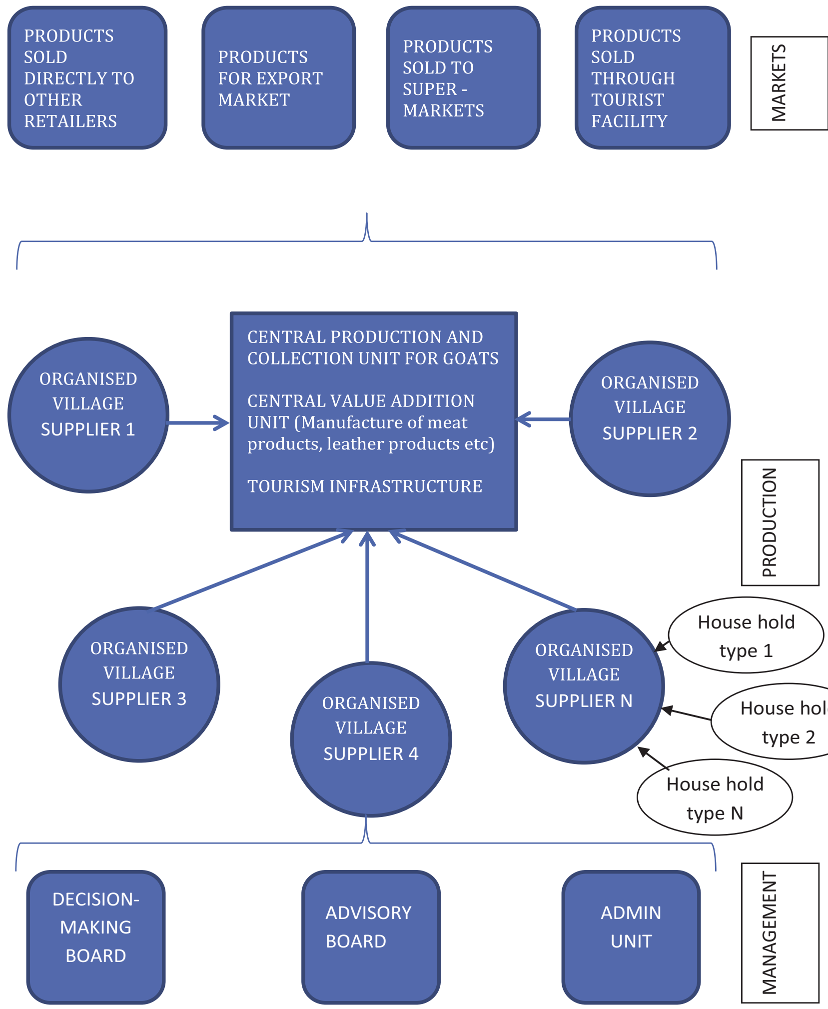

Figure 14.3 Model for commercialization of livestock by farmers in smallholder systems of sub-Saharan Africa.

their stakeholders. It strengthens linkages at various levels, for example, households on low performing systems will learn from those on high performing ones during field days and demonstrations. Research will provide the vehicle of shift from a low performing system to a high performing one. Stakeholder forums will play a key role for timely feedback and provides the platform for specification of roles for stakeholders.

The proposed setup will support the development of the livestock value chains on production, and products processing and set appropriate strategies, regulations, and institutional arrangements necessary for their commercialization. The issue of breed conservation has attracted attention at a global level, whereby the responsibility is bestowed on the country of origin of the breed. The indigenous breeds may meet the future market demands and conservation shall be both in situ and ex situ. Marketing of processed products of livestock will help farmers by creating more reliable marketing chain. The set-up of the proposed livestock marketing system will enhance the delivery of livestock inputs and services to livestock farmers through the setting-up of the livestock breeding and conservation units, targeted extension services, research, and better linkages between stakeholders. The establishment of localized livestock processing units at the central point provides an important marketing infrastructure giving reason for livestock households to shift their mindsets from subsistence to commercialization. Several strategically organized trainings will help in strengthening the capacity of goat farming communities and their link with private sector. The establishment of stakeholder forums will help strengthen the communication between private and public institutions to provide better services to the livestock sector.

14.2.4 Research Gaps

Some of the knowledge gaps of climate change impacts on livestock-based systems and livelihoods of livestock farmers exist and these need urgent attention for the development of livestock value chains:

- Rangelands and feed quantity and quality: The impact of climate extremes will affect the primary productivity, veld species distribution, and can change the overall nutrition for livestock. As species either survives or becomes extinct due to CO_2 and other reasons the feed quality and quantity will remain important questions for livestock planners. Species composition will be shaped by competitive factors leading to changes in the carrying capacities of rangelands (Thornton et al., 2009).
- Potential for mixed crop–livestock systems: Productivity in both the subsystems will affect the overall outlook of agriculture. Climate impacts that are localized will have an effect on primary productivity; there could be shifts in harvest indexes and the availability of stover and crop residues for livestock will change thereby affecting the production.
- Heat stress: Temperature extremes will become more frequent and hence the average temperatures may increase in some locations. It is not clear to what extent extreme heat will affect livestock production?

- Diseases and disease vectors: Climate change will affect the prevalence of pest, vectors, and diseases. Livestock movements based on the disease challenges will need to be restricted further. This will affect breeding programs and more strict regulations will need to be enforced and this may affect the development of livestock.
- Biodiversity will respond to climate extremes and this may challenge the current benefits from ecological biodiversity; however, the change in species densities as systems change is not known.
- Projecting future needs: Animal breed biodiversity is based on the current germplasm, will genetic resources will be useful, superior, and adaptive?
- Ecosystem services associated with livestock systems: Climate change may enhance services from livestock and how these changes on ecosystems goods and services will occur are not clear.
- Indirect impacts: Human beings consume livestock products and in southern Africa this is related to increase in disposable income. How will human health impacts of climate change intertwine with livelihood systems and vulnerability?

14.3 CONCLUSION

Livestock production is affected by population and availability of land for grazing. Climate change will affect the quality of feed produced in smallholder farming systems. Adaptation and mitigation of GHG are required to improve the efficiency of livestock systems. Breeding is required to preserve the gains of yesteryears and to build on the successes to produce and support climate smart livestock systems.

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