4 Impact of Climate Change on Livestock Production and Reproduction

John Gaughan and A.J. Cawdell-Smith

Abstract

There is little doubt that climate change will have an impact on livestock performance in many regions and for most predictive models the impact will be detrimental. The real challenge is how do we mitigate and adapt livestock systems to a changing climate? Livestock production accounts for approximately 70 % of all agricultural land use, and livestock production systems occupy approximately 30 % of the world's ice-free surface area. Globally 1.3 billion people are employed in the livestock (including poultry) sector and more than 600 million smallholders in the developing world rely on livestock for food and financial security. The impact of climate change on livestock production systems especially in developing countries is not known, and although there may be some benefits arising from climate change, however, most livestock producers will face serious problems. Climate change may manifest itself as rapid changes in climate in the short term (a couple of years) or more subtle changes over decades. The ability of livestock to adapt to a climatic change is dependent on a number of factors. Acute challenges are very different to chronic long-term challenges, and in addition animal responses to acute or chronic stress are also very different. The extents to which animals are able to adapt are primarily limited by physiological and genetic constraints. Animal adaptation then becomes an important issue when trying to understand animal responses. The focus of animal response should be on adaptation and management. Adaptation to prolonged stressors will most likely be accompanied by a production loss, and input costs may also increase. Increasing or maintaining current production levels in an increasingly hostile environment is not a sustainable option.

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4.1 Introduction

It is somewhat misleading to focus our discussion on potential livestock production and reproductive losses due to climate change. For a start we do not really know what these losses will be in 20, 30 or 100 years due to the interrelationships between climate, the environment and the animal. Of course human intervention is also a complicating factor, and some animals will adapt. It is easy to model production losses. We know what the impact of high temperature will be on a Holstein dairy cow producing 40 L of milk per day and we know the impact on a cow producing 19 L of milk per day. Similarly, for many of the traditional farm animals, we know the effect of exposure to hot conditions (Nardone et al. 2010). In contrast, we know little about some of the indigenous breeds that are used in many developing countries. One area in which we have little knowledge is the responses to extreme events which are likely to be a feature of climate change. So what should we do? What we need to focus on is how to ameliorate the negative effects of climate change on livestock production. We need to focus on animal adaptation and focus on planning for extreme events – this includes pre, post and during the event.

Livestock production accounts for approximately 70 % of all agricultural land use, and livestock production systems occupy approximately 30 % of the world's ice-free surface area (Steinfeld et al. 2006). Globally 1.3 billion people are employed in the livestock (includes poultry) sector and more than 600 million smallholders in the developing world rely on livestock for food and financial security (Thornton et al. 2006). For many smallholders livestock not only provide food but also provide a source of income that gives livelihood. Meat and milk consumption is increasing especially throughout the developing world due to improved living standards of the middle class (Delgado 2003). In 1973, approximately 6 % of caloric intake in the developing countries was obtained from beef, pork, goats, sheep, milk and eggs (Delgado 2003). In 1997, this had risen to approximately 10 % (Delgado 2003). In 2009, livestock products contributed 17 % to kilocalorie consumption and 33 % to protein consumption globally, but there were large differences between rich and poor countries (Rosegrant et al. 2009).

It has been estimated that agricultural production will need to increase 60 % (based on 2005–2007 production values) just to meet the demand from an increasing world population (FAO 2013). Estimates of future demand for animal-based proteins vary, but based on current growth, and the potential negative impacts of climate change on the livestock sectors in many countries, it is unlikely that food from livestock and poultry will be able to meet demand. The impact of climate change on livestock production systems especially in developing countries is not known, and although there may be some benefits arising from climate change (e.g. in northern Europe there are potential increase in crop yields (Olesen and Bindi 2002)), most livestock producers will face serious problems (Thornton et al. 2009). Furthermore, there is a growing shift in livestock production away from temperate dry areas to warmer, more humid and potentially more disease-prone environments (Steinfeld 2004). Potentially, these are areas that are more vulnerable to climate change. On account of changes in land use, there are shifts in livestock production and also changes in crop production (Thornton et al. 2009; Nardone et al. 2010). Both of these complicate the debate on how climate change will impact livestock production.

Climate change will impact on livestock systems in many ways, some of which are direct effects, e.g. heat stress, water availability, water quality, feed availability, feed quality, disease/parasites and disease/parasite vectors. Indirect effects may include human health issues that are influenced by climate as well as non-climate factors (Thornton et al. 2009). Other indirect effects include land degradation (due to overstocking) and market access. The indirect effects although important are outside the scope of this chapter. The focus of this chapter will be on the impact of climate change on production and reproduction in livestock. The focus will not be on production losses per se but how we might reduce the impact of climate change on livestock.

4.2 Impact of Climate Change on Animal Production and Reproduction

4.2.1 General Response to Climate Change

Climate change may manifest itself as rapid changes in climate in the short term (a couple of years) or more subtle changes over decades. The ability of livestock to adapt to a climatic change is dependent on a number of factors. Acute challenges are very different to chronic long-term challenges, and in addition animal responses to acute or chronic stress are also very different. The extents to which animals are able to adapt are primarily limited by physiological and genetic constraints (Devendra 1987; Parsons 1994). Animal adaptation then becomes an important issue when trying to understand animal responses. For example, should we try to enhance adaptive capacity through selective animal breeding or use breeds that are already adapted? An adjunct to this question is: are we focused on increasing animal performance (and hence food production) or simply family survivability? Unfortunately increased 'genetic' performance often leads to an increase in input costs and an animal that is more susceptible to harsh conditions. The ability of animals to cope with climatic extremes (more on this later) is influenced by their level of production. For example, high production Holstein dairy cows (>30 kg milk/day) exposed to high heat load had a 13.7 % reduction in milk yield compared with low production cows (<19 kg milk/day) which had a 4.1 % reduction under the same climatic conditions (Gaughan and Lees 2010). Further to this, reproductive rates fell by more than 20 % in the high production cows. Placing high production cows into a hot environment is not sustainable, and if there is an increase in extreme events, then selection of animals that can cope with these events is critical. Angus steers have faster growth rates and are more efficient in turning grain-based diets into meat than Brahmans are when lot fed, but Angus are also more susceptible to heat stress (Fig. 4.1). The higher rumen temperature of the Angus is an indication that they are not adapted to hot conditions. However, other factors will need to be considered.

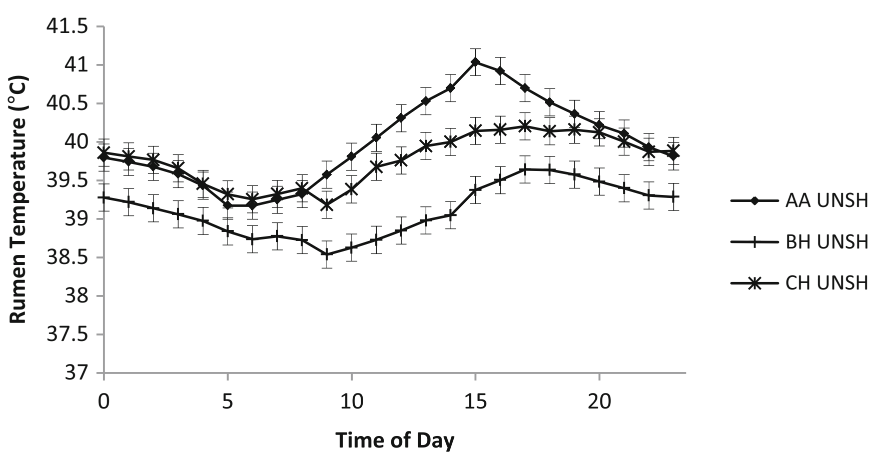

Fig. 4.1 Hourly rumen temperatures of unshaded Angus (AA), Charolais (CH) and Brahman (BH) steers in a feedlot over summer in Queensland, Australia (Gaughan unpublished)

4.2.2 Animal Adaptation

The introductory arguments suggest that livestock and poultry production will not meet the human demand for meat, milk and egg products due to the negative impacts of climate change. On this premise what can be done to improve animal performance when they are being challenged by a changing climate? Much has been said about the need to select animals that are adapted to certain climatic (or environmental) conditions or select those that have the capacity to adapt. However, adaptation is not necessarily a simple process and selection for this may be difficult.

Animal adaptation is a function of a number of intertwined factors, i.e. animal × human × resources. Animal adaptability in the face of a changing climate is as much about the animal as it is about the adaptability of humans and their use of the available resources (e.g. land, feed, water and money). Any discussion about animal adaptability needs to encompass all of the factors that will either enhance adaptability or reduce adaptability. There is another underling question. Should we be looking for adaptability in farm animals or should we focus on genotype, i.e. only use animals that are already adapted to the conditions? Or should we look for alternatives, e.g. changing from cattle to goats?

Furthermore, there are a number of issues facing livestock systems in much of the developing world and in parts of the developed world. These factors need to be addressed as prerequisites to animal adaptation. Some of these are:

- Low productivity (genetic)
- Low productivity (environment)
- Low productivity (G × E)
- Availability of land
- Availability of feed
- Availability of water
- Land degradation (natural, cropping, livestock)
- Capacity to adapt or change
- Cultural norms (prestige of owning livestock)
- Market access (and a fair price)

Effective management of livestock and nutrition under suboptimal conditions, rather than maximum production or selection for adaptability, may be a more realistic goal. Grazing livestock can improve soil fertility, reduce woody weeds and increase grass growth and reduce fire hazards. But only if the animals are managed correctly – overgrazing is a management issue not an animal issue.

The effects of climate change will be exacerbated where there is a lack of animal and resource management. Adaptation to climate change is more than adaptation to heat. Unfortunately, much of the focus has been on the potential for elevated heat in the future and in particular extreme heat events (which we will discuss below). It is difficult even with the most technologically advanced nations to select animals for climate extremes without a major reduction in the animals' performance. Therefore, there is a need to focus on the big picture. How will a changing climate impact on the animals' overall environment? Again a number of interacting factors need to be considered, and these include precipitation (variation and extremes), soil moisture, feed resources, parasite exposure, solar load, temperature (variation and extremes) and drinking water availability.

There is a growing need to select animals (and species) that are suited to the current climatic conditions, as well as the predicted future conditions. This is not an easy task. First, the future is largely unknown. Secondly there is a considerable breed variation, within and between breeds, for thermal tolerance and overall stress tolerance. The ability of livestock breeders to identify phenotypes, which carry specific genes, is difficult partly because phenotypic variance is due to the combined effects of genetic and environmental components. Therefore, there is a reliance on selecting animals from within the environment or from a similar environment in which they are expected to live. Livestock need to have 'adequate' performance in four key areas:

- Survivability (to reproductive age)
- Productivity (milk, wool, meat, egg production)
- Productivity
- Fertility

It can be argued that a reliance on 'natural' selection is fundamentally the correct approach (but it may not be quick enough). However, animals with adequate survival rates under harsh conditions may achieve this survivability at the expense of growth, production and fertility. Furthermore, the extent to which a location is likely to be favourable or unfavourable to the species or breed concerned at some point in the future needs to be considered. The time taken to fundamentally change the genetics of a breed is dependent upon the number of animals in a breeding programme, the fertility of the population, selection pressure (on the traits of interest), selection differential, the heritability of the trait concerned, and the generation interval. Reaching a desired goal may take 15–20 years (or longer). In a static environment this is probably not an issue, but if climate is changing, where do we head with a breeding programme? If predicted changes are wrong, a breeder may be 20 years into a breeding programme only to find they made the wrong decisions years ago.

In a further complication, livestock breeders are generally more concerned with local climatic conditions than regional or global change because the local changes have the biggest immediate impact on animal performance and it is this current performance that biases selection. It is unlikely that a smallholder will be able to do much to enhance genetic change in their animals without financial and technological assistance.

In the context of livestock production – what can be achieved? In the 2013/2014 drought in Queensland, Australia, cattle losses due to a lack of feed and water were high. However, the ability to move cattle (adjistment, feedlotting or selling) reduced mortality but was expensive. Even in a developed nation, a lack of financial resources will reduce options for short-term and long-term adjustment. Financial setbacks due to droughts, floods, fires and disease further reduce the capacity for livestock producers (large and small) to adapt to change. Furthermore, it is not possible for animals to adapt to no food and no water. Extreme events are likely to be more problematic in any selection programme for adaptation than the overall change in temperature. Nyong et al. (2007) studied the value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. In their conclusion, they made a salient comment that has application in both developed and developing nations: 'Reducing vulnerability entails the strengthening of adaptive capacities of vulnerable individuals and groups. Capacity building should emphasize the need to build on what exists, to utilize and strengthen existing capacities.' This statement applies broadly to the global livestock sector.

4.2.3 Heat Stress

Generally climate change is associated with an increasing global temperature. Various climate model projections suggest that by the year 2100, mean global temperature may be 1.1–6.4 °C warmer than in 2010 (Nardone et al. 2010). In many cases, animals and livestock systems will be able to adapt to an increased mean temperature (provided other factors such as feed and water remain available). The difficulty facing livestock is weather extremes, e.g. intense heat waves. In addition to production losses, extreme events also result in livestock death. There is little doubt that there has been an increase in extreme events since the 1990s. Documented heat wave mortalities for livestock include some 50,000 feedlot animals in North America between 1990 and 2014 and 12,000 feedlot steers in Australia between 1990 and 2014; 26,000 dairy cows died in California in July 2006; it was estimated that 700,000 poultry died during the July 2006 heat wave, and during a heat wave in India (2007), more than 800 peacocks died. It is likely that animal deaths are considerable in developing countries as well. Unfortunately data is mostly non-existent. Further to this, extreme events are often multifactorial, e.g. drought + heat, so categorising the cause of death as heat or drought is not easy. Livestock deaths are costly, not only is future income forgone, but past expenses are also not recovered. There is also a cost associated (in some countries) with carcass disposal. It should not be forgotten that major heat waves also kill humans. The 2003 heat wave that occurred in Europe left 35,000 dead, during the 2012 Russia event 15,000 died and a heat wave in

Andhra Pradesh killed more than 500 people in 2013. It is clear that extreme events are the problem and it is the uncertainty and irregular occurrence of these events which make management difficult.

Production/reproduction losses due to heat stress are well documented for sheep, pigs, poultry, beef cattle and dairy cows, although most of the research focuses on large-scale intensive production systems in developed countries. The proceeding few paragraphs will only discuss heat stress (generally) for dairy cows, poultry and beef cattle. This does not imply that the other species are not worth discussing. The reader is encouraged to look for the scientific literature to further their knowledge in this area.

4.2.3.1 Dairy Cows

Holstein-Friesian dairy cows are particularly vulnerable to heat stress (see West 2003). When ambient temperature exceeds 25 °C, dairy cows are subjected to heat stress (Staples and Thatcher 2011). The first manifestation of heat stress is an increase in body temperature and respiration rate (Fig. 4.2). As body temperature increases, there is a concurrent reduction in feed intake and a reduction in milk output (West 2003; Staples and Thatcher 2011). The magnitude of reduced production is, as mentioned earlier, a function of the degree of heat load and genetic merit of the cow. Staples and Thatcher (2011) reviewed a number of studies. They reported that when rectal temperature increased from 38.8 to 39.9 °C, there was a reduction in milk output from 22.4 to 19.2 kg/day. Dry matter intake also fell. Although data is limited, there is evidence that higher production cows are more susceptible to heat stress than are low production cows. A comparison of three studies (Staples and Thatcher 2011) shows that there is a difference in the heat stress response between high and low production cows with the high production cows (32.6 kg milk/day) having a 4.7 kg/day decrease in milk production compared with a 2.7 kg reduction in the low production cows (19.0 kg milk/day) (Table 4.1). Lower reductions were reported by Gaughan and Lees (2010). In a study, 150 Holstein-Friesian cows were studied over 120 days of summer. The cows were not housed and were subjected to natural Australian (Queensland) summer conditions. High production cows (34.4 kg milk/day) had a 2.3 kg per day reduction in milk yield compared with low production cows (<20 kg) where there was no change in milk yield. Reproductive performance of dairy cows also declines during heat stress. As with production losses, the impacts on reproduction are well documented (Jordan 2003; Hansen and Furquay 2011). There also appears to be a relationship between the level of production and fertility. Al Katanani et al. (1999) reported that during summer the fertility depression in Holstein cows was greater for high production cows (>9,072 kg milk) as compared to low production cows (<4,536 kg). Fertility depression was assessed by non-return rates (i.e. the number of cows that do not return to oestrus 21 days postinsemination). The non-return rate for the low

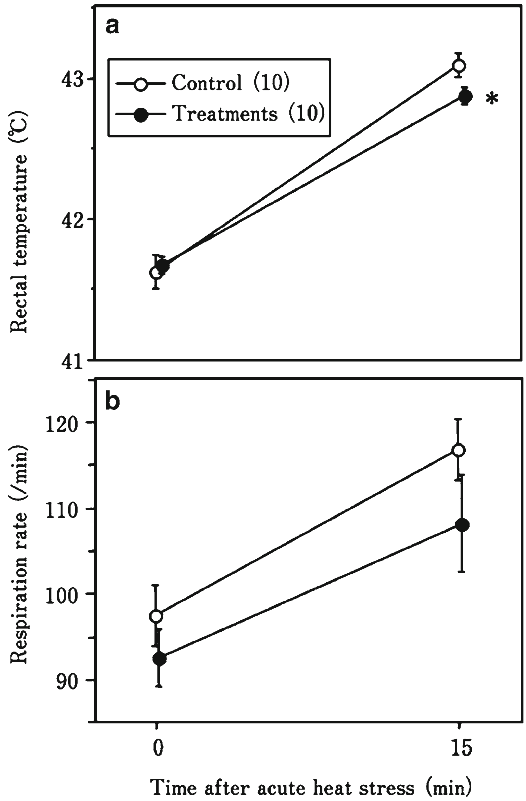

Fig. 4.2 Effect of environmental temperature on respiration rates and rectal temperatures of lactating dairy cows (Staples and Thatcher 2011)

Table 4.1 Differences in dry matter intake (DMI) and milk yield between low and high production dairy cows exposed to heat stress

	Low production cows (<25 kg milk/day)	High production cows (>30 kg milk/day)
Change in rectal temperature (°C)	38.9–39.9	38.5–39.8
Change in DMI (kg/day)	17.4–15.0	21.3–17.5
Change in milk yield (kg/day)	19.0–16.3	32.6–27.9
Reduction in milk output (kg) per 1 °C increase RT	2.7	3.6

Adapted from Staples and Thatcher (2011)

production cows was 44.9 % and for the high production cows the non-return rate was 5.3 %.

4.2.3.2 Poultry

Poultry production is expanding worldwide with much of the growth in developing countries in the tropics and sub-tropical zones. Heat stress is likely to be a major limiting factor in poultry production in many regions. Given that the optimum temperature for broilers is 18–22 °C (Lin et al. 2006), projected climate change scenarios are a major concern for the global poultry industry (Tanizawa et al. 2014). Because of this, more heat stress-related research has been undertaken for poultry than any other farm animal. Heat stress impacts on performance (reduced egg production, reduced growth rate), reduces product quality, decreases immune function and leads to an increase in mortalities (Sahin et al. 2013). Poultry (broilers) are probably more susceptible to heat stress than other farm animals due to their selection for rapid growth and feed efficiency (Lin et al. 2006). Selection for heat tolerance has not been a major consideration by breeding companies primarily because heat tolerance means reduced performance (Washburn et al. 1980). However, Yahav and Hurwitz (1996) demonstrated that thermotolerance could be induced in chickens by exposure to high temperatures at an early age. This is a continuing area of research and many researchers have demonstrated higher heat tolerance in poultry where embryos are exposed to high temperature for short periods (Fig. 4.3). Thermal conditioning resulted in significant ($P<0.05$) reductions in rectal temperature compared with non-treated birds (42.87 vs. 43.09 °C, respectively) and also for respiration rate (108.2 vs. 116.8 breaths/min) (Tanizawa et al. 2014).

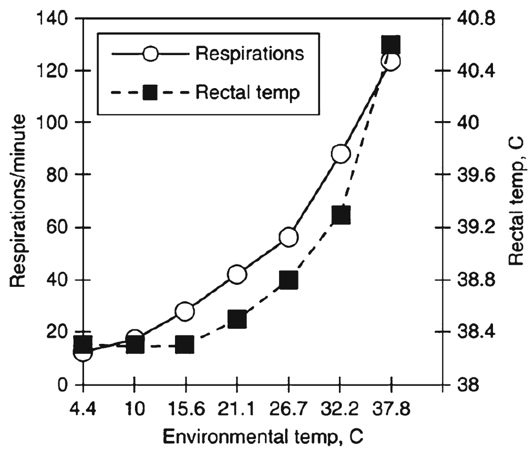

Fig. 4.3 Rectal temperature and respiration rate of chickens before and after thermal conditioning (From Tanizawa et al. 2014)

4.2.3.3 Beef Cattle

The effects of heat load on different breeds of cattle (*Bos indicus*, *Bos taurus* and various *Bos indicus* × *Bos taurus* crosses) have been reviewed by a number of authors, e.g. Blackshaw and Blackshaw (1994), Finch (1986), Hammond et al. (1996, 1998), Gaughan et al. (1999), and Beatty et al. (2006). *Bos indicus* breeds (e.g. Brahman), although having greater heat tolerance than *Bos taurus* breeds (Fig. 4.4), often have lower productivity (growth rate and reproductive efficiency) than the less heat-tolerant breeds (Gaughan et al. 2010). The normal respiration rate for *Bos taurus* cattle under thermoneutral conditions is 20–30 breaths per minute. Under extreme heat stress, respiration rate may exceed

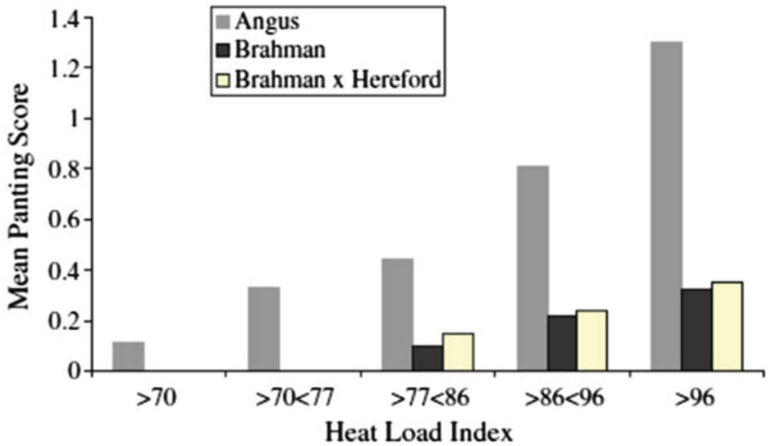

Fig. 4.4 Differences in panting score and heat load (the higher the value the greater the heat stress) for Angus, Brahman and Brahman × Hereford steers (Gaughan et al. 1999)

150 breaths per minute. Rectal temperatures may increase from 38.6 to 41.5 °C. When faced with hot ambient conditions, cattle (especially grain-fed cattle) reduce their feed intake. An inverse relationship between ambient temperature and feed intake exists for beef cattle. During periods of high heat load, dramatic drops in feed intake occur. A 17 % reduction in feed intake was reported by Brown-Brandl et al. (2005) for unshaded heifers when mean ambient temperature increased from 19.7 °C (maximum 21 °C) to 27.7 °C (maximum 35 °C). A depression in intake of 3–5 % has been reported to occur when ambient temperature increases from 25 to 35 °C; intake reductions go beyond 30 % when temperatures exceed 35 °C. Reduced production as a result of reduced feed intake is the major issue facing beef cattle exposed to chronic heat stress.

Reproductive performance of beef cattle is also affected by ambient conditions; however, there is little published data. In a US study, Amundson et al. (2006) reported that pregnancy rate decreased when the minimum night-time temperature exceeded 16.7 °C and temperature humidity index was greater than 72.9 units.

4.3 Can Livestock Adapt to Climate Change?

Returning to our original question – can livestock adapt? When environmental conditions change, an animal's ability to cope (or adapt) to the new conditions is determined by its ability to maintain essential functions and oxidative metabolism (Pörtner and Knust 2007). As we have discussed, environmental stressors brought about by climate change include reductions in available feed and water, changes in temperature and an increase in extreme events. The individual stress response to these challenges is influenced by a number of factors including species, breed, previous exposures to the stressor, health status, levels of performance, body condition, metabolic state (e.g. pregnant, lactating), mental state and age. To further complicate things, the stressors may be acute, sudden changes (usually short term, e.g. hours to days) in weather, or chronic, prolonged (weeks to months) exposure to stress. Animal responses to acute and chronic stressors may be very different. If we are looking for animals adapted to climate change do we select for acute or chronic stress? Given the earlier premise that selection for extremes is difficult, selection should probably focus on chronic environmental stress.

If an animal is not acclimated or adapted, then its physiological, behavioural and metabolic responses will most likely be different to when it is acclimated or in adapted. It is important therefore, while discussing animal adaptation, to understand that animal responses to a given set of stressors may change over time as the animal adjusts. It is possible that acclimatisation or adaptation may alleviate the stress response (Kassahn et al. 2009), but performance may not return to prestress levels. And this is the conundrum that livestock producers face. Adaptation is often at the expense of performance, and survivability is often better in 'low'-performance animals because their input needs (especially feed) are not high.

4.4 Conclusion

There is little doubt that climate change will have an impact on livestock performance in many regions and for most predictive models the impact will be detrimental. The real challenge is how do we mitigate and adapt livestock systems to a changing climate. Should the focus be on animal adaptation or an overall adaptation of the systems involved? Farmers need to adapt and invoke strategies that will reduce the impact of climate change. The capacity of animals to adapt in the short to medium term will be limited primarily by their genetics. However, financial resources and management capacity will have a major role. Adaptation to prolonged stressors will most likely be accompanied by a production loss, and input costs may also increase. Increasing or maintaining current production levels in an increasingly hostile environment is not a sustainable option. It may be wiser to look at using adapted animals, albeit with lower production levels (and also lower input costs), rather than try to infuse 'stress tolerance' genes into a non-adapted breed. This may be contrary to government policies and can be counter intuitive. It is not always easy to convince someone that they are better off with a cow that produces 9 L of milk per day versus one that produces 20 L. Perhaps a better solution is to change species, e.g. use goats instead of cattle. Animal adaptation is one part of the solution but it is not the solution to protect food resources in a changing climate.

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