Projected Impacts of Climate Changes and Sustainability of Sheep Production Systems

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Abstract

Sheep production plays a major role in terms of meat, milk and fibre production in countries that are very susceptible to climate change. Climate change will have both direct and indirect effects on sheep production systems and the effects are largely multi-faceted and it is difficult to adequately predict how all of the underlying factors will interact. The indirect effects of climate change on sheep production especially in regard to nutrition may have a greater impact than the direct effect of ambient temperature. The low availability of pastures during summer was found to be the most crucial factor reducing sheep production. Further, exercise stress was found to be an important stress, particularly in extensive system of rearing, which negatively influences the production potential of sheep. Although the production potential of sheep is influenced by climate change-induced sudden disease outbreaks, it remains a largely unexplored area of research. Therefore, developing appropriate strategies involving management of rangelands, disease surveillance and genetic selection of sheep for greater heat tolerance may offer longer term solutions to sustain sheep production in the changing climate scenario.

Keywords

Exercise stress • Genetic selection • Heat stress • Pasture management • Sheep

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V. Sejian et al. (eds.), *Sheep Production Adapting to Climate Change*,
DOI 10.1007/978-981-10-4714-5_8

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8.1 Introduction

Sheep are an important food and fibre source in many countries and approximately 25% of the global ruminant population is sheep (Marino et al. 2016). The global sheep population was approximately 1.2 billion in 2013 (FAO 2016). China has the largest sheep population (202 million), followed by Australia (72 million) and India (63 million). Sheep production plays a major role in terms of meat, milk and fibre production in countries that are very susceptible to climate change, for example, India (65 million), Pakistan (29 million), Mongolia (23 million) and Afghanistan (13 million) (FAO 2016). Further, there is considerable world trade in live sheep and sheep meat. In 2013, approximately 16 million live sheep were traded around the world. Major exporters included Somalia (2.2 million) and Australia (1.9 million) (FAO 2016). Although live export represents a small percentage of the global sheep population (1.3%), it is nevertheless an important food source for some countries (e.g. Qatar and Saudi Arabia imported 409,000 and 597,000 live sheep, respectively, in 2013). Sheep are an important global food source and like other livestock are potentially vulnerable to climate change.

Climate change will have direct and indirect effects on sheep production systems. Thornton and Gerber (2010) outlined the direct and indirect effects of climate change on grazing livestock. The direct effects were extreme weather events, water availability, drought and floods and productivity losses (physiological stress) due to temperature increase. The indirect effects were fodder quantity and quality, disease epidemics and host pathogen. In this chapter, the primary focus will be on the effects of climate change on grazing sheep production, and secondly on diseases and parasites.

8.2 Impact of Climate Change on Sheep Production

It is well established that climate change will lead to reductions in feed availability (pasture and fodder crops), reduced quality of feedstuff, reduced quality and quantity of water, increased risk of diseases and parasites, and an increase in adverse local weather conditions (heat stress and solar load) (Harle et al. 2007; Thornton and Gerber 2010; Kenyon et al. 2009; Nardone et al. 2010). All of these are likely to have negative effects on sheep production not only in regions where production is already curtailed by harsh conditions but also in currently benign areas such as Europe.

8.2.1 Sheep Production and Climate Change

The relationship between sheep production system and climate change is complex (Thornton et al. 2009). The impact of climate change is multi-faceted and it is difficult to adequately predict how all of the underlying factors will interact. It is unlikely however that sheep will be exposed to only a single climate change-induced stressor. In a recent study, Sejian et al. (2016) demonstrated the effects of multiple stressors (heat, nutrition and exercise) on the physiological, blood biochemistry and the endocrine system of Malpura rams. The exercise component is primarily walking, the suggestion being that sheep will need to forage longer and cover a greater distance to find adequate feed due to the effects of climate change on pasture production and water availability. Therefore, it is conceivable that the indirect effects of climate change on sheep production especially in regard to nutrition may have a greater impact than the direct effect of ambient temperature.

8.2.2 Effect of Climate Change on Grazing

Due to a lack of resources, an already variable climate, and a reliance on grazing, it is likely that sheep production in developing countries will be adversely affected by climate change, especially in areas where rainfall is already decreasing (Rischkowsky et al. 2008). However, this is not just a developing country problem. Sheep production in developed countries such as Australia which is largely rangeland based is also very susceptible to climate change (Harle et al. 2007). Reduced rainfall in the Mediterranean Basin is also likely to have negative effects (Seguin 2008) on sheep production. Interestingly, Harle et al. (2007) also stated that in regions where rainfall is predicted to increase, such as New Zealand and parts of China, there may actually be an increase in sheep production. However, the production modelling shows mixed results. Modelling by Ghahramani and Moore (2016) shows the change in live weight of sheep across various sites in Western Australia × potential climate combinations ranged between −3% and +3%, and gross margin varied between −11% and +6%. So, while modelling suggests that impact of climate change on meat and wool sheep production is mixed, the impacts on milking sheep production are mostly negative, probably because the common milk sheep breeds (especially in Europe) are highly susceptible to heat stress. Finocchiaro et al. (2005) reported a 4.2% reduction in daily milk yield when milk sheep (Valle del Belice breed) in the European Mediterranean Basin were exposed to natural heat stress. Heat stress also results in reductions in feed intake which have implications for growth and reproduction. This suggests a direct effect on the biology of the animal. Genetic selection of sheep with greater heat tolerance from within the susceptible milk breeds is the likely longer term solution.

The growth and quality of pasture and fodder crops may be affected by changes in rainfall amounts and variability as well as higher atmospheric CO_2 concentrations (Harle et al. 2007). Pasture response to climate change is complex due to interactions between direct climate drivers such as CO_2 concentration, temperature and precipitation, and indirect effects such as seasonal productivity and plant–animal interactions (Porter et al. 2014). A number of studies have suggested that an increase in CO_2 concentration coupled with warmer conditions will improve pasture growth via a longer growing season and increased photosynthesis (Anderson et al. 2001; Tubiello et al. 2007; Ghahramani and Moore 2016) of C3 plants. The impact on C4 plants appears to be limited (Thornton et al. 2013). Kenyon et al. (2009) stated that "*The climate in the UK is changing, with a trend towards increased rainfall in the autumn and winter and warmer average temperatures throughout the year. There has also been a 4-week extension of the herbage growing season over the past 40 years*." Potentially, the changes in pasture productivity could lead to increased sheep production in some areas. The modelling by Ghahramani and Moore (2016) suggests that pasture growth in Western Australia would be enhanced by increased CO_2 especially in lower rainfall areas, but gains may be offset by other aspects of climate change such as increased incidence and severity of heat waves. Furthermore the nutrient availability of plants may be negatively affected when plants are exposed to higher temperatures. Minson (1990) reported that increased temperatures increase lignification of plant tissues, which leads to lower rates of degradation in the rumen. So, again potential gains in pasture production for sheep may be offset in this case by reduced digestibility of the plants. Romanini et al. (2008) suggested that the predicted temperature rises of 2–5°C could negatively impact on grazing capacity in Brazil by up to 50%. Although the Romanini et al. (2008) study was based on beef cattle, there is no reason to doubt that sheep production could be adversely affected as well by reductions in pasture quality especially in areas where reductions in rainfall are part of the climate change mix. The capacity for sheep production in tropical highlands cannot be overlooked. Higher temperatures may lead to improved plant productivity in parts of the tropical highlands where cool temperatures currently constrain plant growth (Thornton et al. 2013).

Low soil fertility, land degradation and a loss of palatable plant species are already problems in many of the world's rangelands. These problems have been mostly human-induced via overstocking, poor land management and harsh climatic conditions. Unfortunately, climate change is likely to exacerbate these problems especially in drier climate zones (Ghahramani and Moore 2016). These are the very areas where sheep production is of high importance. However, there are potential solutions. Rischkowsky et al. (2008) stated that although drought-tolerant plant species have been introduced into rangelands in the West Asia and North Africa (WANA) region, there are problems associated with land tenure (communal ownership) and a lack of land management policy. There is little doubt that the potential for increased sheep production in WANA is possible. But for this to be achieved there will need to be structural changes in land management and water policy.

8.2.3 Mixed Farming

Mixed farming (i.e. grazing sheep plus crops production) is already a common and well-established practice in many regions. Mixed farming options are typically less risky in variable climates than cropping alone (Ghahramani and Moore 2015). It is therefore possible that sheep production could expand in areas where cropping is currently in decline or predicted to decline. This is primarily due to the greater potential impacts climate change could have on crop production, e.g. effects of drought on dry-land cropping. Livestock are already used as an insurance against drought in many areas (Seo and Mendelsohn 2006; Rust and Rust 2013). Indeed in a recent study, Ghahramani and Moore (2016) stated that sheep production was more reliable than cropping in drier areas. Mixed farming may therefore serve as a transition from full reliance on cropping to full reliance on sheep production. But there are inherent risks with this strategy especially where water resources are limited. In areas where climate change modelling suggests reductions in rainfall, the risks to sheep production are high.

8.2.4 Diseases and Parasites

A considerable amount of work has been undertaken to investigate the potential impacts of climate change on the spread of diseases and parasites in humans (Thornton et al. 2009). However, similar studies on sheep populations have not been carried out to the same extent. It remains unclear how climate change will affect sheep health. In some instances increased temperatures and rainfall may increase parasite growth, and the opposite may occur if rainfall is lower. Again, it is a complex story.

It is also necessary to keep in mind that importance of a sheep disease/parasite is somewhat dependent on the resources that are available to deal with the problem. Hence a disease of minor importance in Europe may be of major importance for small holders in Africa. This is not because sheep are necessarily more susceptible to the disease in Africa but simply the financial resources may not be available to vaccinate against the disease. Grace et al. (2015) listed the top 15 diseases in Africa that are likely to become more of a problem with climate change. All of these are currently endemic in the regions listed in the Grace et al. (2015) report. The important message here for sheep production is that as animals are exposed to greater stress (due to droughts, heat, etc.) they become more susceptible to diseases/parasites.

Changes in parasite populations show the complexity of climate change and their epidemiology with respect to climate change is largely unknown. Positive aspects associated with longer growing seasons, greater rainfall and warmer temperatures are all favourable not only for pasture production but also ideal for some parasites. It is possible that climate change might alter parasite epidemiology and therefore the effectiveness of current control strategies (van Dijk and Morgan 2008). This has major management implications. The occurrence of outbreaks of sheep parasites such as *Haemonchus contortus, Nematodirus battus, Teladorsagia circumcincta* and *Fasciola hepatica* in southeastern Scotland was associated with warmer wetter conditions, a consequence of climate change (Kenyon et al. 2009). In addition, a study was undertaken by Bosco et al. (2015) in southern Italy to determine the relationship between outbreaks of acute fasciolosis in sheep and weather conditions. These authors showed that that there was a direct relationship between changes in climate (warmer and wetter) and the outbreak of fasciolosis.

However, it remains unclear if changes in parasite populations in sheep are driven only by climate change. Kenyon et al. (2009) state that there is a need to determine the current prevalence of helminth parasitism in the UK and provide a benchmark to measure any future changes. This would be a useful strategy for the control and prevention of diseases and parasites affecting sheep worldwide. Further, there is a need for a better understanding of the parasites themselves, especially in regard to how they adapt to climate change.

As an example bluetongue virus (BTV) which causes bluetongue disease in ruminants that adversely affects sheep, and cattle and goats to a lesser extent. It is a common disease in the tropics and sub-tropics, but also spreads into the temperate regions of Australia. The emergence of BTV in Europe has been put forward as an example of the spread of a disease due to climate change. BTV would occasionally appear in southern Europe when climatic conditions were favourable for its spread from North Africa (Gould and Higgs 2009). However, it has now spread throughout much of Europe including the UK. Gould and Higgs (2009) concluded that the spread of BTV into Europe was only partly due to climate change. Other factors such as wind-borne midges which are the insect vectors for the disease and the transport of infected animals into clean areas also play a role (Gould and Higgs 2009; Grace et al. 2015).

8.3 Conclusion

Climate change is complex and multi-faceted. There is currently (apart from studies done in Australia) a paucity of information on how climate change will impact on sheep production. However, it is likely that only small holder production systems in the developing world, in particular much of Africa, the Middle East, Pakistan and India, which will be adversely affected by climate change. It is also predicted (and to an extent already seen) that there will be less rainfall, higher temperatures and an increase in extreme events (droughts and flooding). Overall, there will be both positive and negative outcomes on sheep production from climate change.

The positive outcomes include:

- Improved pasture production in areas with C3 grasses due to higher concentrations of atmospheric CO_2, which may lead to greater productivity from sheep. And the effect may be greater in dry areas.
- Increased sheep production in tropical highlands as increased temperature and rainfall improve pasture yields.
- Longer growing seasons create a greater biomass, thereby improving sheep productivity.

The negative outcomes include:

- Decreased milk production and overall productivity in milk sheep.
- Increased CO_2 concentration will have little effect on tropical C4 grasses.
- Increased incidence of extreme weather events (droughts, heat waves, floods) could offset the positive outcomes and exacerbate the rundown of already fragile production systems.
- Increased risk of disease and parasites; however, it is largely unknown how changing disease/parasite challenges will impact on sheep production.

Some potential solutions:

- Government strategies to better manage rangelands, especially communal ownership of lands, and better water management.
- Genetic selection of sheep for better heat tolerance within existing sheep breeds (long-term approach).
- Disease surveillance – knowledge of the current scenario.
- Develop better understanding of the genetics and biology of the vectors, viruses, bacteria and parasites that affect sheep.

References

Anderson LJ, Maherali H, Johnson HB, Polley HW, Jackson RB (2001) Gas exchange and photosynthetic acclimation over subambient to elevated CO_2 in a C3–C4 grassland. Glob Chang Biol 7:693–707

Bosco A, Rinaldi L, Musella V, Amadesi A, Cringoli G (2015) Outbreak of acute fasciolosis in sheep farms in a Mediterranean area arising as a possible consequence of climate change. Geospat Health 9:319–324

Finocchiaro R, van Kaam JBCHM, Portolano B, Misztal I (2005) Effect of heat stress on production of Mediterranean dairy sheep. J Dairy Sci 88:1855–1864

Food and Agricultural Organisation FAO (2016.) http://www.fao.org/faostat/en/#data/QA. Accessed 20 Nov 2016

Ghahramani A, Moore AD (2015) Systemic adaptations to climate change in southern Australian grasslands and livestock: production, profitability, methane emission and ecosystem function. Agric Syst 133:158–166

Ghahramani A, Moore AD (2016) Impact of climate changes on existing crop-livestock farming systems. Agric Syst 146:142–155

Gould EA, Higgs S (2009) Impact of climate change and other factors on emerging arbovirus diseases. Trans R Soc Trop Med Hyg 103:109–121

Grace D, Bett B, Lindahl J, Robinson T (2015) Climate and livestock disease: assessing the vulnerability of agricultural systems to livestock pests under climate change scenarios. In: CCAFS working paper no. 116. Copenhagen, Denmark. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

Harle KJ, Howden SM, Hunt LP, Dunlop M (2007) The potential impact of climate change on the Australian wool industry by 2030. Agric Syst 93:61–89

Kenyon F, Sargison ND, Skuce PJ, Jackson F (2009) Sheep helminth parasitic disease in south eastern Scotland arising as a possible consequence of climate change. Vet Parasitol 163:293–297

Marino R, Atzori AS, D'Andrea M, Iovane G, Trabalza-Marinucci M, Rinaldi L (2016) Climate change: production performance, health issues, greenhouse gas emissions and mitigation strategies in sheep and goat farming. Small Rumin Res 135:50–59

Minson DJ (1990) Forage in ruminant nutrition. Academic, San Diego

Nardone A, Ronchi B, Lacetera N, Ranieri MS, Bernabucci U (2010) Effects of climate changes on animal production and sustainability of livestock systems. Livest Sci 130:57–69

Porter JR, Xie L, Challinor AJ, Cochrane K, Howden SM, Iqbal MM, Lobell DB, Travasso MI (2014) Food security and food production systems. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. In: Contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge/New York, pp 485–533

Rischkowsky B, Iñiguez L, Tibbo M (2008) Management practices for adapting sheep production systems in the WANA region to climate change. In: Rowlinson P, Steele M, Nefzaoui A (eds) Livestock and global climate change, Hammamet, Tunisia 17–20 May, 2008. Cambridge University Press, Cambridge, pp 107–110

Romanini CEB, Nääs IDA, D'Alessandro Salgado D, Lima KAO, do Valle MM, Labigalini MR, de Souza SRL, Menezes AG, de Moura DJ (2008) Impact of global warming on Brazilian beef production, Livestock environment VIII, 31 August – 4 September 2008, Iguassu Falls, Brazil 701P0408

Rust JM, Rust T (2013) Climate change and livestock production: a review with emphasis on Africa. S Afr J Anim Sci 43:255–267

Seguin B (2008) The consequences of global warming for agriculture and food production. In: Rowlinson P, Steele M, Nefzaoui A (eds) Livestock and global climate change, Hammamet, Tunisia 17–20 May, 2008. Cambridge University Press, Cambridge, pp 9–11

Sejian V, Kumar D, Gaughan JB, Naqvi SMK (2016) Effect of multiple environmental stressors on the adaptive capability of Malpura rams based on physiological responses in a semi-arid tropical environment. J Veter Behav Clin Appl Res 17:6–13

Seo SN, Mendelsohn R (2006) Climate change impacts on animal husbandry in Africa: a Ricardian analysis. In: CEEPA discussion paper No. 9, Centre for Environmental Economics and Policy in Africa, University of Pretoria, South Africa

Thornton PK, Gerber P (2010) Climate change and the growth of the livestock sector in developing countries. Mitig Adapt Strateg Glob Chang 15:169–184

Thornton PK, van de Steeg J, Nitenbaert A, Herrero M (2009) The impacts of climate change on livestock and livestock systems in developing countries: a review of what we know and what we need to know. Agric Syst 101:113–127

Thornton PK, Boone RB, Ramirez-Villegas J (2013) Climate change impacts on livestock. In: Working paper No. 120, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

Tubiello FN, Soussana JF, Howden SM (2007) Crop and pasture response to climate change. Pro Natl Acad Sci USA 104:19686–19690

Van Dijk J, Morgan ER (2008) The influence of temperature on the development, hatching and survival of Nematodirus battus larvae. Parasitology 135:269–283