Invited Paper

Research and development on climate change and greenhouse gases in support of climate-smart livestock production and a vibrant industry

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Abstract

Climate change represents a feedback-loop in which livestock production both contributes to the problem and suffers from the consequences. The impact of global warming and continued, uncontrolled release of greenhouse gasses (GHG) has twofold implications for the livestock industry, and consequently food security. Firstly, the continuous increase in ambient temperature is predicted to have a direct effect on the animal, as well as on food and nutrition security, due to changes associated with temperature itself, relative humidity, rainfall distribution in time and space, altered disease distribution, changes in the ecosystem and biome composition. Secondly, the responsibility of livestock production is to limit the release of greenhouse gases (GHG) or the carbon footprint, in order to ensure future sustainability. This can be done by implementing new or adapted climate-smart production systems, the use of known and new technologies to turn waste into assets, and by promoting sustainable human diets with low environmental impacts. The following elements, which are related to livestock production and climate change, are discussed in this paper: (1) restoring the value of grasslands/rangelands, (2) pastoral risk management and decision support systems, (3) improved production efficiency, (4) global warming and sustainable livestock production, (5) the disentanglement between food and nutritional needs, focusing on nutrient rich core foods, (6) GHG from livestock and carbon sequestration, and (7) water and waste management. No single organization (or industry) within South Africa can perform this research and the implementation thereof on its own. The establishment of a (virtual) centre of excellence in climate-smart livestock production and the environment for the livestock industries, with the objective to share research expertise and information, build capacity and conduct research and development studies, should be a priority.

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Introduction

Food production has undergone a revolution in the last 40 years and is now globalised in a free market economy. Developed countries have developed large-scale, intensive and extensive, industrial systems of livestock and crop production which produce affordable food. Even today, however, 70% of world food is produced by several billion small-scale/subsistence/communal farming families, livestock keepers and pastoralists in Africa, Asia and Latin America (Hodges, 2013). Industrial food production and these small-scale producers will have to work together in harmony to successfully feed the exploding world human population.

Climate change also poses both immediate and long-term threats to the life-support systems upon which all people depend – food, water, habitat, health and the ecosystem – as climate change is taking place faster than originally thought. Rural, small-scale, subsistence and communal farming families will ultimately be affected the most. Furthermore, population growth will continue through the year 2050 and will be accompanied by high rates of urbanization and a higher income, especially in developing countries, which will result in a rapid growth in demand for food, in both quality and quantity. It is projected that global

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livestock production will have to double by the year 2050 and the majority of this growth will have to occur in the developing world (Steinfeld *et al*., 2006; Mitloehner, 2013).

Knowledge exists to improve efficiencies in livestock production. What is called for, however, is sustainable, climate-smart animal agriculture, coupled with technology transfer from developed to developing communities, to supply in the growing demand for animal protein using sustainable and climate-smart production practices.

Livestock food (all food of animal origin) and rice are the two most important single food sources for the developing world. However, these two food sources are also responsible for the production of large quantities of anthropogenic methane. Livestock (16% from enteric fermentation and 5% from animal waste) is responsible for 21% and rice cultivation for 12% of anthropogenic methane (see Figure 1).

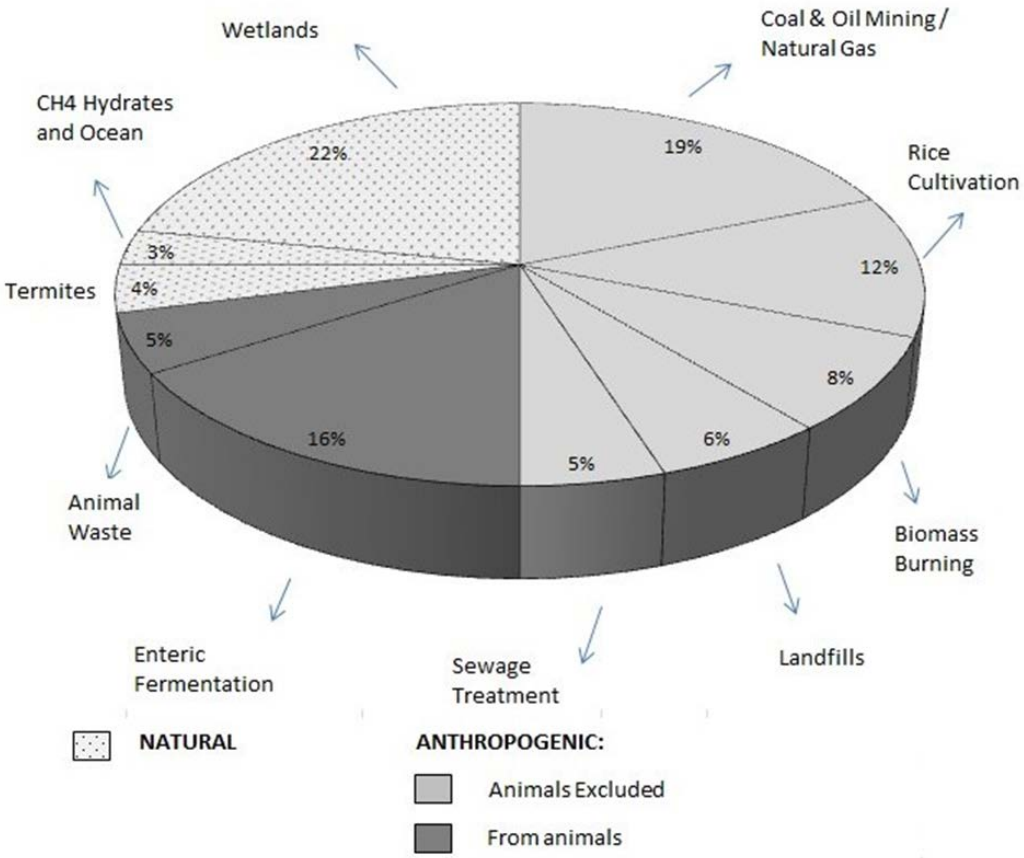

Figure 1 Sources of anthropogenic methane production (adapted from Augenbraun *et al*., 2010).

The uncontrolled anthropogenic (man–made) release of greenhouse gases (GHG) into the atmosphere is thought to be the primary cause of a systematic and unprecedented increase in sea and earth surface temperatures. A survey by the American Association for the Advancement of Science (AAAS) indicates that 97% of climate scientists have concluded that anthropogenic climate change is happening (AAAS Climate Change Panel, 2014). The major greenhouse gases are carbon dioxide (CO_2) and methane (CH_4). Of the two, CO_2 is by far the most abundant with an atmospheric concentration of 49%, compared to 18% CH_4. However, the global warming potential of CH_4 is approximately 23 times more than that of CO_2 - resulting in it being a significant role player in the greenhouse gas emission family. While CO_2 releases result mostly from non-agricultural activities (power plants, deforestation, transport, oil and gas production, and manufacturing), CH_4 results primarily from the enteric fermentation of plant material in the digestive tract of animals and fermentation of their waste e.g. manure and sewage sludge (Clark *et al*., 2001; IPCC, 2007; Biotech Ltd, 2009). CH_4 emission is therefore a concern and the responsibility of agriculture as a whole and livestock farming in particular, to reduce these emissions.

Reduction in CH_4 levels will have a significant effect on the greenhouse gas (GHG) reduction targets set by governments, since its impact will be quicker, due to the shorter lifetime, and bigger, due to the higher heating potential, than CO_2. More emphasis on the reduction of methane emissions from livestock can thus be expected in the immediate future.

Discussion

Livestock and rice are unique in the sense that climate change represents a feedback-loop within which livestock and rice production both contribute to the problem and suffer from the consequences. The impact of global warming and continued uncontrolled release of greenhouse gas (GHG) thus has twofold implications for livestock production and, consequently, food security.

Firstly, the continuous increase in ambient temperature is predicted to have a direct effect on water supplies, the future distribution of livestock species and breeds, their adaptability to an increased heat load, incidence and type of diseases, feed supplies, grazing potential, and human food (nutrition) security. This is because of the changes associated with temperature itself, relative humidity, rainfall distribution in time and space, altered disease distribution, changes in the ecosystem and biome composition, woody species encroachment, and alien plant invasion (Linington, 1990; Scholtz *et al*., 2011; Scholtz *et al*., 2012). An improved understanding of the adaptation of livestock to their production environments is important, but adaptation is complex and thus difficult to measure. Fortunately, several proxy-indicators for adaptation, such as reproductive, production and health traits, are available. The selection of animals and genotypes that are better adapted to the production system, including heat stress, is possible and should be pursued to ensure sustainable production in hotter climates (McManus *et al*., 2008; Scholtz *et al*., 2013b).

Secondly, the responsibility of livestock production is to limit the release of GHG (i.e. the carbon footprint) and the use of water (i.e. the water footprint) in order to ensure future sustainability. This can be done through improved production efficiency, breeding to reduce the carbon footprint of livestock products by implementing new or adapted climate-smart production systems, by the use of known and new technologies that can limit GHG emissions and turn waste into assets, and by promoting sustainable human diets with low environmental impacts (Capper, 2013; Scholtz *et al*., 2013a)

Both these aspects should be the focus of any climate change related livestock research and development programme to support best practices (climate-smart) in livestock production in the era of climate change. The information on research and development presented in this article is mainly influenced by:

- The National Conference on Global Change that was held in Boksburg from 26 to 28 November, 2012.
- Research and Development Plan for the Focus Area: Climate change and sustainable livestock production, of the large and small stock industries, as updated by Red Meat Research and Development South Africa in 2013 (RMRD, 2013).
- The 3rd Multi-stakeholder Platform Meeting (Global Agenda of Action in support of sustainable livestock sector development) that was held in Kenya from 22 to 24 January, 2013.
- The Climate Change Workshop between the livestock industries, researchers and academics that was in Pretoria on 30 January, 2013.
- The 11th World Conference on Animal Production that was held in China from 15 to 20 October, 2013.
- The BRICS seminar on Agriculture and Climate Change that was held at Muldersdrift from 23 to 25 October, 2013.
- The 3rd Global Conference on Agriculture, Food Security and Climate Change that was held in Johannesburg from 2 to 5 December, 2013.

The different elements discussed below are aimed at addressing the comprehensive issues that are related to livestock production and climate change, and are all in support of the overarching aims, which are climate-smart livestock production systems and a vibrant livestock industry in the era of climate change.

Restoring the value of grasslands/rangelands

Widespread neglect and degradation of grazing land has led to high incidences of poverty in many rural areas. The degradation of grasslands also results in environmental losses, e.g. erosion, CO_2 emissions, water loss and biodiversity loss. The primary objective should be to restore both environmental and economic value to grasslands, while preserving its social and cultural functions. The approach should be broad enough to include an assessment of existing policy, legislation, strategies, projects and programmes aimed at improving the grassland resources for sustainable climate-smart animal agriculture (Meissner *et al*., 2013).

If rangeland/grassland vegetation recovers it will increase carbon sequestration in biomass, improve climate change resilience and improve production efficiency. The needs of rural people also need to be addressed, as many are still completely dependent on the grasslands and livestock.

Pastoral risk management and decision support systems

Management and decision-making by pastoralists would be greatly enhanced by the availability of risk identification/evaluation and decision support systems. The provision and development of databases based on sound research results should provide the necessary inputs for the development of risk management and decision support tools. This should include decision support tools whereby the stock farmer can be informed in time of environmental risks (e.g. drought and/or floods) and extreme events (e.g. temperature, both high and low), so that the farmer can employ strategies to minimize the negative effects.

Improved production efficiency

An effective way to reduce the carbon and water footprint from livestock is to reduce the livestock numbers and increase the production per animal, thereby improving their productivity. Increased productivity generates less GHG emissions per unit of livestock product (Scholtz *et al*., 2013a). Production efficiency can be improved through breeding, feeding management and alternative production systems; all these strategies should be researched. There is sufficient genetic variation in South Africa's livestock genetic resources to facilitate breeding for improved production efficiency. One such strategy then is the effective use of crossbreeding (Scholtz *et al*., 2010; Scholtz *et al*., 2013a).

The GHG emissions per unit livestock output in South Africa can also be reduced substantially if the comparatively low fitness (reproductive rate and longevity) can be addressed (Meissner *et al*., 2013). Alternative traits to improve production through selection within breeds should be investigated, such as days to calving, kilogram meat produced/Large Stock Unit (LSU), residual feed intake, residual daily gain, or derivations thereof, combined in a multi-trait selection index (Hendriks *et al*., 2013; Mokolobate *et al*., 2013, Scholtz *et al*., 2013a).

Other strategies that should be investigated include systems and management strategies, and the manipulation of nutrition (Leeuw & Scholtz, 2013), including breeding of new forage and pasture cultivars to increase production efficiency. Carbon credits can be generated through efficiency gains, but it is still uncertain how this is measured and validated.

Methane production by ruminants is one of the largest sources of anthropogenic methane and it will be advantageous if CH_4 production can be reduced via nutritional approaches. In the ruminant, rumen bacteria, protozoa and fungi break down feed to produce volatile fatty acids, CO_2, ammonia and hydrogen, while the rumen methanogens use hydrogen and other elements to form CH_4. If the hydrogen can be removed from the rumen, less methane will be produced. Mitigating CH_4 losses from ruminants thus has economic, as well as environmental, benefits. There are many practices that are effective, but not appropriate for long-term mitigation of CH_4 emissions in ruminants. It is therefore necessary to develop long-term strategies in suppressing CH_4 production, without detrimental effects on the performance of the animal (Zhu & Cheng, 2013). An integrated research approach investigating the animal, plant, microbes and nutrition strategies may result in a long-term solution for CH_4 production.

Global warming and sustainable livestock production

Global warming is expected to have more extreme effects on Africa than the other continents (Scholtz *et al*., 2013b). The anticipated global warming will change the southern hemisphere's environments and vegetation and this will have a negative effect on the livestock production environments, which will impact on the political, economic and social issues.

The effects of global warming on sustainable livestock production are related to the effect of ambient temperature (heat stress, nutritional stress, lowered production/reproduction), climate (rainfall, humidity, solar radiation), altered patterns of animal and plant diseases (threats of new disease, frequency of existing diseases), nutritional value of pastures and change in pasture composition (growth, yield and stocking rate) and the adaptation of animals to the production environments. Ambient temperature is thus the factor that has the largest direct effect on livestock production, while nutritional stress has the largest indirect effect on the grazing animal in the tropics and subtropics (Scholtz *et al*., 2013b).

Livestock in the southern African countries will need to adapt to higher ambient temperatures, lower nutritional value of the grass in some cases, and the expansion of diseases, especially ticks and tick borne diseases, as a result of global warming. With such challenges, matching genotypes with production environments will become crucial (Scholtz *et al*., 2013a; b). The development of mitigation strategies and a livestock discomfort index are therefore recommended.

The disentanglement of food and nutrition needs

Global human population growth will continue to drive the demand for responsibly produced foods and nutritionally adequate, healthy and affordable diets. The disentanglement of the food and nutritional needs, which focus on nutrient rich foods, should be addressed to enable the development of strategies towards “environmentally-friendly production (climate-smart) and processing,” while supporting healthy, well-nourished populations (Schönfeldt *et al*., 2013a). In addition to the formulation of strategies aimed at greener food environments, health considerations (such as nutrient-density), as well as carbon footprint calculations, should be considered. Choosing nutrient-rich foods and reducing the intake of nutrient-poor energy dense foods is one way of reducing the amount of food (and resources) required to meet nutritional needs.

In anticipation of the 2014 Second International Conference on Nutrition (ICN2) organized by the United Nations, The Rome Accord (a draft political outcome document) recognized that the multiple threats of malnutrition are a major challenge to global development. It provides a vision for global action to end all forms of malnutrition and reshaping current food systems to improve people’s nutrition in a sustainable way (WHO, 2013). One of the specific draft outcomes acknowledges that food systems should produce more nutritious foods, not just more food, and guarantee adequate supply of fruit and vegetables, unsaturated fat and animal source foods, while avoiding excess sugars, saturated and trans fats and salt. Food systems should enhance nutrition by providing year-round access to macro- and micronutrients, promoting food safety and balanced diets, and avoiding food processing that reduce or adversely affects nutrition (WHO, 2013).

Any reduction in the consumption of meat and dairy products may compromise the dietary intakes of those nutrients that meat and dairy products supply in relatively large proportions. The risk is greatest where those nutrients are already in short supply or where there is evidence of low status. For children in South Africa this includes energy, protein, vitamin A, vitamin C, thiamine, riboflavin, niacin, vitamin B_6, folate, Vitamin B_{12}, iron, zinc and calcium. The lower bioavailability and quality of these nutrients from plant-based sources should also be taken into consideration when comparing different food sources (Schönfeldt *et al*., 2013b). It is therefore important not to overlook the importance of animal products in providing bio-available mineral nutrients (Laker, 2005).

With respect to consumption, the amount of food and energy consumed is the factor with the strongest effect on the environmental impact of the food source. The consumption of more food than the daily human requirements and the waste of food from production to consumption, need to be part of a holistic approach to considering a sustainable diet (Schönfeldt *et al*., 2013b).

In terms of protein produced per unit of water, animal products are more efficient than fruit and other food crops, such as grains and vegetables (Renault & Wallender, 2000; Wenhold *et al*., 2007). If the predictions are correct the demand for livestock products will continue to increase in future, but will progressively be affected by competition for natural resources, contention over animal feed and human food, and the need to operate in a carbon-constrained and water shortage economy (Thornton, 2010).

GHG from livestock and carbon sequestration

In general, estimates of emissions from livestock are subject to uncertainty, as generic coefficients applicable to all animals are commonly used and take no account of differences in production efficiency and production systems. The lack of detailed GHG emissions (also sequestration) and water usage data for the South African livestock industry should therefore be addressed. Previous GHG inventories were mainly based on the IPCC methodologies, which are inadequate and inaccurate (Meissner *et al*., 2013). The inventories did not include all livestock species, production systems and the energy costs of feed production, feed and livestock transport, and livestock product processing. If viable, the official LSU system used in South Africa should be used in gas emission and water usage reporting, as this will facilitate information transfer and link the data to current livestock management practices (Scholtz *et al*., 2013c).

It is important to calculate the carbon sequestration potential of the natural and cultivated grazing areas utilized in South African livestock production systems and the GHG emitted from grassland fires. Downstream aspects that also need attention include techniques to accurately measure GHG, carbon sequestration and the water footprint; as well as databases of national and regional emission figures (Meissner *et al*., 2013).

Water and waste management

The effects of production system, fertility, mortality and replacement rate all influence the water usage of livestock. It is therefore essential that total life cycle analyses are done to accurately estimate the water footprint of livestock production in South Africa.

Apart from reducing GHG emissions and waste, a positive approach would be to utilize these emissions and waste to the benefit of the environment. Downstream aspects that need attention are methane capturing and energy generating units/plants, the treatment of manure and waste that limits CH_4 release and water use, management of agricultural wastes and effluents to limit water pollution, and the application of techniques and methods to earn carbon credits from the livestock value chain (RMRD, 2013).

It is important that the energy left in the manure is recovered to substitute fossil energy. Efficient use of this resource for biogas constitutes a major potential for counteracting the emission of greenhouses gases of producing livestock products. It has been estimated that utilizing manure from pig production for biogas has the potential to reduce the carbon footprint of pork meat by 27% (Nguyen *et al*., 2010).

Conclusion

It is important that through research, development and management interventions, methods or innovative ways are developed and put in place to reduce the GHG production from livestock and to mitigate the effects of climate change on livestock production. All the livestock industries should recognize the effect of livestock on climate change and actively support strategies to mitigate it. No single organization (or industry) within South Africa can do this research and the implementation thereof on its own. Academics, researchers and industries should therefore combine their efforts. The establishment of a (virtual) centre of excellence in climate-smart livestock production and the environment for the livestock industries, with the objective to share research expertise and information, build capacity and conduct research and development studies should be a priority.

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