A Systems Approach to Climate Change Impacts on Livestock Production

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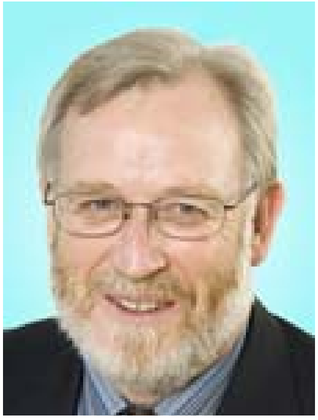

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Livestock production is doubly impacted by climate change — it both contributes to the phenomenon and must adjust to its consequences. Whilst adaptation is being achieved, the true mitigation potential for livestock production is yet to be quantified. The situation is exacerbated by the fact that demand for animal products is escalating quickly, especially in developing and transitional economies. The sector is also subject of considerable biological variability, meaning that the industry does not fit easily into carbon trading schemes. Any response to climate change will need to consider changes in productivity to reduce emissions per animal; changes in consumption to restrict the total animal population; and policy or regulation changes as governments make difficult decisions on mitigation targets. There is a need to improve the reliability and applicability of regional impact models, to enable a system-wide assessment of climate change effects. Similarly significant gaps exist in our knowledge of the basic biology of animals, and especially the rumen. In the absence of new information for research, progress to reduce the current and projected impacts of livestock production will be slow.

Introduction

Climate change poses a challenge for livestock production that is not easily addressed, and an effective response is likely to involve changes in the consumption of animal products, in regulation and policy, and in productivity of production systems.

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Any examination of climate change and animal agriculture must consider three factors:

- First, the extensive land use and dependence on reliable weather by livestock production means that it is exposed to climate change impacts on a scale more significant than that for most industries.
- Second, it is a major source of greenhouse (GHG) emissions, and biological variability means that the sector is not conducive to mitigation actions, nor does it fit easily into carbon trading schemes.
- Third, global demand for animal production is resulting in rapid expansion of the animal population, particularly in transition and developing economies, thus adding further to total GHG emissions.

GHG emissions from animal agriculture have been long recognised to be a function of the efficiency of production (productivity) and of total numbers (see Bootsma 1994). Thus improved productivity is required to reduce emissions, and on a per-animal basis this has been achieved in many areas of the world. Efficiency gains, however, have been negated by increases in production so that the total contribution by livestock to climate change continues to grow. The mitigation potential for animal agriculture is yet to be determined (Plume *et al.* 2008) and there are significant gaps in knowledge of the processes surrounding the production of GHGs from animals (Kebreab *et al*. 2006).

'Livestock's long shadow' and global development

The 1999 publication of *Livestock to 2020 — The Next Food Revolution* by the International Food Policy Research Institute (Delgado *et al*. 1999) has had a major impact on the understanding of the critical role of animals in global development and poverty reduction, and provided clear evidence of the current and projected expansion of demand for animal products.

At the time that IFPRI released its study, there was already an emerging argument that the development of 'environmentally friendly' livestock production systems demanded that production increases should be met by improved productivity, and not by an increase in animal numbers nor expansion of land area under production (Leng 1993). Whilst this objective may be achievable in developed agricultural systems, it has clearly not impacted in the transition and developing economies.

A second important study, *Livestock's Long Shadow* from the FAO (Steinfeld *et al.* 2006), suggested that the global effects of the animal sector have remained unappreciated; a sentiment strongly shared by others (McMichael *et al.* 2007; Thorne 2007; Koneswaran and Nierenberg 2008).

The Steinfeld *et al.* (2006) study highlights a number of factors:

- Animal numbers are expected to double by 2050, with most increases occurring in the developed world.
- Animal agriculture contributes 18% of global business-induced GHG emissions.
- Livestock production accounts for 35–40% of global anthroprogenic methane emissions, and 65% of global anthroprogenic nitrous oxide emissions. (Methane and nitrous oxide have respectively 23 and 296 times the global warning potency of carbon dioxide.)
- While methane and nitrous oxide are the key GHG emissions from livestock production, the sector also impacts:
  - indirectly (primarily the result of fertiliser production for feed crops, on-farm energy, and transport and processing)
  - directly (primarily through deforestation and desertification) on CO_2 production, and contributes about 9% of total global CO_2 emissions.
- Livestock production contributes about 80% of the contribution of agriculture to GHG emissions.

Viewed alone, the climate change impacts of livestock production are alarming. Measures to reduce GHG emission that significantly curtail livestock production seem a simple and logical solution. When, however, they are viewed against the impact of animal agriculture on the breaking of the poverty cycle of poorer communities, and on global development in general, it is not so evident that a clear decision path exists. Nor is there clear pathway when re-investment costs are considered.

Climate change impacts on livestock production

Climate change effects on livestock production fall into two categories: those relating to increases in climate variability and frequency of extremes, and those relating to longer-term shifts in the eco-physical characteristics of regions.

The former result in greater frequency, duration and severity of flooding, and of drought. These add to the complexity of day-to-day livestock management and result in production losses, increased costs and longer-term degradation of pastoral lands. Significant social and economic disruption and costs are associated with these events, which are subject of major regional or country studies such as Fleischer and Sternberg (2006) and Stokes and Howden (2008). Widespread land degradation as a result of livestock production is reported in many areas of the world including northern China (Lin *et al.* 2007) and the Sudan (UNEP 2007).

Shifts in the eco-physical characteristics of regions are more benign but nonetheless significant. Changes in the patterns of rainfall and ranges of temperature affect feed availability, grazing ranges and feed quality, and weed, pest and disease incidence. As a result producers will need to adjust production systems and land use patterns. For example, it is forecast that New Zealand will become warmer, and that rainfall will become more variable (Table 1). As a result pasture productivity will increase, although in the

Table 1. Projected climate change impacts, New Zealand 1970–1999 to 2070–2099

Region	Change in temperature (°C)	Change in rainfall (%)
Northland, Auckland	+1.0° to +2.8°C	–10% to 0%
Western North Island from Waikato to Wellington	+0.8° to +2.7°C	0% to +20%
Eastern North Island from Bay of Plenty to Wairarapa	+0.9° to +2.7°C	–20% to 0%
Nelson, Marlborough, to coastal Canterbury and Otago	+0.8° to +2.5°C	–20% to +5%
West Coast and Canterbury foothills	+0.6° to +2.2°C	+5% to +25%
Southland and inland Otago	+0.6° to +2.2°C	0% to +30%

Source: Kenny (2001)

north production may decline as pasture quality declines due to encroachment of sub-tropical grass species such as paspalum and kikuyu. In the east of the North Island a greater incidence of drought is expected.

Other examples of impacts of climate change include changes in the ranges of diseases, such as the spread of bluetongue virus into the UK (Gale *et al.* 2008), or re-emergence of threats from previously endemic diseases such as Rift Valley disease (Fields 2008) and east coast fever (Olwoch *et al.* 2008) in sub-Saharan Africa. Globally there is a need to fully examine the potential impact of the extension to the ranges of mosquitoes, tsetse fly and ticks that are anticipated as a result of temperature increases. Both animal and human health will be increasingly vulnerable to insect-borne disease risks (Sutherst 2001, 2003).

Climate change, especially increases in temperature, has a direct impact by increasing heat stress in animals. This results in both a loss of production (largely through reduction of feed intake) and reduced reproductive efficiency (Baker *et al.* 1993; Smit *et al.* 1996).

Mitigating the impacts of climate change on livestock production

A range of technologies and management strategies at both the regional and on-farm scale exist to enable the impact of climate change to be mitigated. In China, for example, where widespread climate-induced instability in animal agriculture is reported since 1980 (Lin *et al.* 2007) a range of responses are being introduced including:

- better determination of grazing capacity of pastures in terms of climate change
- halting over-grazing and avoiding grassland degradation
- stopping and reversing the trend of desertification to enhance the resilience of livestock production to climate change.

Another example of regional responses is seen in a series of studies on livestock production in Africa (see Kurukulasuriya *et al.* 2006; Seo and Mendelsohn 2007) that have shown that small-holders have been able to change their species mix (principally moving from large ruminants to sheep and goats) in response to climate change. Larger enterprises with greater reliance on cattle have been unable to adjust and experience increased costs and loss of production as a result.

For regional responses to be fully effective there appears to be a need to reduce the present levels of uncertainty in impact assessment studies (Lin *et al.* 2007). The uncertainties of impact assessment come from four main sources:

- Understanding of climate change effects on various ecosystems and the interactions among them is limited.
- Not all factors are considered in the existing impact assessment models.
- The impacts of climate change on trade and socio-economic development is seldom included.
- Insufficient consideration is given to the effects of adaptation measures on reducing the vulnerability of livestock production to climate change.

There is little doubt that assessment of climate change impacts requires complex modelling on a regional basis. Despite problems, the reliability of models is improving, with impacts generally rising with more recent studies. Stern (2007), in particular, points to more serious concerns in the loss of agricultural productivity in both developed and developing regions of the world.

The response of the developing and developed economies is understandably different. Where economics allow, mechanical interventions such as use of artificial shade and evaporative cooling systems in animal enclosures (Frank *et al.* 2000) are available to ameliorate environmental impacts. In the developed economies, however, responses to climate change at the individual farm level appear not to have been well studied. A five-year study by Smit *et al.* (1996) in Canada suggests that:

- Farmers experience effects of climate change, but simply absorb them and make no strategic changes to their operations in response.
- Problematic climatic conditions are translated into economic stimuli, so that changes are attributed to economic rather than climatic forces.
- The effects of climate are swamped by those of variations in costs, prices, technologies and so on.

In addition to changes in production systems and production mixes, considerable opportunity exists to breed animal genotypes adapted to the changing conditions resulting from climate change. The CSIRO livestock improvement program based in Rockhampton, for example, has introduced tropically adapted cattle breeds into northern Australia and greatly improved reproductive efficiency and meat production (Frisch and O'Neill 1998; Prayaga 2004). Major livestock enterprises have used this genetic diversity to develop composite breeds of cattle adapted to our production systems and imparting greater disease resistance, heat tolerance, better capacity to graze and high reproduction rates (Bentley *et al.* 2008). Animals can also be selected on the basis of increased overall feed-use efficiency (Alford *et al.* 2006) to lower the GHG emissions.

Mitigation of livestock production impacts on climate change

The literature on GHG mitigation for livestock production is already large and escalates each year. Koneswaran and Nierenberg (2008) point out that thus far, most mitigation and prevention strategies have focussed on technical solutions such as investigating the reformulation of ruminant diets to reduce enteric fermentation and methane emissions. Whilst some progress has been made to reduce GHG per unit of production by about 20%, some studies, such as McMichael *et al.* (2007) advocate a need for aggressive reductions in meat consumption and restriction of animal numbers to address climate change. Plume *et al.* (2008) contended that the true mitigation potential remains undiscovered.

Improving productivity: growing production — the paradox

A common feature of many developed nations is that GHG emissions from agriculture have been falling (Leslie *et al.* 2008). Some developed countries, however, have not followed this trend. In New Zealand, GHG emissions from agriculture, in particular nitrous oxide and methane from pastoral agriculture have been rising at about 1% per year since 1990 (Ministry for the Environment 2007). Emissions growth has come first from increased individual animal production (meaning each animal consumes more forage and thus produces more methane and excretes more nitrogen). Second, this increased feed consumption has required growth in the use of inorganic nitrogen fertiliser from 52 000 t in 1990 to 345 000 t in 2005. But, while the total amount of GHG from NZ has increased, the amount emitted per unit of production has declined by about 17% (Table 2).

Genetic, nutritional and management strategies have improved animal productivity and lowered emissions in dairy and sheep production (Leslie *et al.* 2008) in NZ, as they promise to do in beef systems in Australia (Bentley *et al.* 2008).

The NZ changes reflect the global paradox livestock production faces. Given production growth projections and current technology, GHG emissions will continue to rise.

Table 2. Methane emissions per unit of production

Year	Dairy sector		Sheepmeat sector	
	Emissions ($Mt\ y^{-1}$)	Emissions per unit production (kg CO_2 equ kg^{-1})	Emissions ($Mt\ y^{-1}$)	Emissions per unit of production (kg CO_2 equ kg^{-1})
1990	4.99	8.32	11.2	2.1
2005	8.51	6.85	9.2	1.7
Change (%)	70.5	–17.7	–18.2	–17.5

Source: Leslie *et al.* (2008)

Whole-of-system approaches at the enterprise level

Attempts are now been made to go beyond simple genetic and nutritional approaches. One Australian pastoral company (NAPCO), for example, is seeking further emission reductions in general farming and grazing systems (Bentley *et al.* 2008). This includes ceasing broad-scale tree clearing, re-establishing native vegetation using permanent pastures and adopting zero-till farming practices. Fossil fuel use is also being reduced by adapting solar power for operations such as water pumping and lighting. The company is also investigating biogas generation from feedlot waste, and is using surplus liquid effluent strategically for irrigation. Solid effluent is been composted for off-farm sale as high-grade organic fertiliser in the horticultural and cropping industries.

Similar approaches (although not all on a whole-of-enterprise basis) are being explored for production of biogas from livestock enterprises in Asia (Liang *et al.* 2008; Su *et al.* 2008) and NZ (Lieffering *et al.* 2008); for treatment of effluent to reduce methane in European systems (Berg and Model 2008) and for reducing nitrous oxides in general (Eckhard 2006; De Klein and Eckhard 2008).

Mitigation of rumen GHG emissions

The literature is rich with studies aimed at rumen manipulation to reduce methane emissions. Approaches range from attempts to directly inhibit methanogens (McAllister and Newbold 2008) to vaccines (Wright *et al.* 2004) to transfer of methanogens between species (Klieve and Hegerty 1999). More recently genetic approaches (Alford *et al.* 2006) and genomics (Attwood and McSweeney 2008) have been commenced. Nutritional management studies continue (Beauchemin *et al.* 2008).

All approaches show merit, but it has been difficult to reliably capture benefits. In some cases inadequate performance of delivery mechanisms, such as controlled-release capsules, has prevented adequate analysis of results (Waghorn *et al.* 2008) Often different approaches do not have an additive impact, and in some cases different treatments can negate each other (McAllister and Newbold 2008).

Wright *et al.* (2006) report that a large proportion of methanogens cannot be cultured and studied in the laboratory, making it possible that non-culturable strains increase to replace those against which control measures are developed. The fact that diet and geography appear to influence the diversity of methanogen populations in the rumen (Wright *et al.* 2007) increases the challenge for rumen interventions.

Attwood and McSweeney (2008) sum up the present situation when they report that it is currently not possible to redirect rumen activity away from methane production into other end-products.

To date productivity interventions have contributed about 20% reduction in per-unit GHG emissions. This is a significant effect given that it has been achieved in the period from 1990. If demand for animal products was static, then meaningful reductions in climate change impacts would be evident. There is no evidence to suggest that this rate of improvement could not be sustained in the next 20 years. Alone, however, it is likely to be insufficient to compensate for the forecast growth in livestock production.

Species selection

Additional to attempts to reduce rumen emissions, to sequester carbon and to reduce CO_2 emissions, it has been suggested that decreasing the portion of rumen products in the total production population would be desirable. Species differences do exist (Table 3) and suggest that greater use of small ruminants, pigs and poultry may be desirable, especially in the development of animal industries in developing countries. There do not appear to be any detailed models, however, to reliably assess these approaches, and so such options should be included in improved regional models discussed earlier.

Non-traditional livestock species also need to be considered. A recent study (Wilson and Edwards 2008) has quantified the GHG savings Australia could make through substituting kangaroo production for cattle and sheep in the rangelands. Removing 7 million cattle and 36 million sheep by 2020 is projected to lower Australia's animal GMG emissions by 3%, and is a proposal that warrants further consideration. Such a change has other environmental benefits, and possibly health benefits, but also presents major social and cultural adjustments, and the study cited did not consider the financial investment required to achieve this shift. Trials of this potential are in their infancy.

Considered from a holistic viewpoint, there is an urgent need to improve our understanding of species (traditional and non-traditional) impacts in production systems and their potential to reduce climate change impacts.

Table 3. Species contribution to GHG emissions (million t of methane per year)

Species	Enteric	Manure
Dairy	15.69	3.08
Beef	50.16	4.41
Buffalo	9.23	0.34
Sheep and goats	9.44	0.34
Pigs	1.11	8.38
Poultry	-	0.97

Source: Steinfeld *et al.* (2006)

Table 4. Daily meat consumption, by region

Region	Daily consumption (g per person)
Africa	31
East and South Africa	112
West Asia (including Middle East)	54
Latin America	147
Developing countries (overall)	47
Developed countries (overall)	224
Total	101
Target under contract–converge model	90

Contract and converge: the challenge of consumption

McMichael *et al.* (2007) advocate a contraction and convergence strategy to reduce GHG emissions. On the assumption that available technologies would reduce non-carbon-dioxide emissions by less than 20%, their calculations indicate the need for a significant reduction in per-capita consumption of livestock product. Contraction of consumption in developed countries would define a lower, common ceiling to which developing countries would converge, or grow.

Assuming that there will be no advances in mitigation technologies and that the world population will grow by 40% by 2050, the contract–converge model has global meat consumption falling to 90 grams per person per day to stabilise emissions at current levels. The effect on daily meat consumptions by region may be appreciated by examining current consumption shown in Table 4.

The scenario also argues that significant health benefits will offset the discomfort of the adjustment in developed countries. The full workability of this approach is difficult to assess:

- First, it assumes no improvement in GHG mitigation technologies. Given that improvements of 17% or better were achieved in some regions from 1990 to 2005, this is a questionable assumption. This reflects some of the difficulties of over-simplification in assessment models.
- Second, there is sufficient variability and inconsistency in measurement of livestock GHG emissions (Kebreab *et al.* 2006; Laubach *et al.* 2008) that the accuracy of the baselines for such a model will be challenged.

- Third, the model looks at health (diet) benefits as well as climate change, but does not take into account the impacts of the livestock sector in breaking poverty cycles and contributing to economic growth in the transition and developing countries. There are wider trade-offs to be considered.
- Fourth, the study superficially covers the full social and cultural impacts, but does not consider the considerable re-investment and new investment needed for such a fundamental restructuring of animal agriculture.

Whilst the contract–converge scenario is feasible and attractive, it requires further validation and testing against a fuller range of assumptions. In its current form, it is unlikely to meet with widespread support because of the uncertainty of the actual mitigation potential.

Concluding remarks

There is little doubt that climate change is a serious issue for livestock production.

Climate change impacts on animal production are manifested mainly at a regional level, and could be more readily addressed were it not for the fact that livestock production also contributes significantly to the problem itself.

Similarly the critical roles that animals play in poverty reduction and development in transition and less developed economies cannot be ignored. The resultant increases in demand will result in continued growth of GHG emissions globally.

Given the present state of knowledge, it is not possible to envisage an industry program that would contain and reduce global emissions from animals without seriously compromising the aspirations of developing nations and the rural poor. Further improvements in productivity will be achieved, but recent evidence suggests these will not keep pace with growth in total production in the sector.

From a technical perspective two needs exist. The reliability and usefulness of regional impact models need urgent improvement so that there can be more confidence in baseline measurements and better appreciation of the true magnitude of targets to be achieved. A better understanding of productivity at the animal, or production unit, is needed, including a fuller exploration of rumen biology. The level of research being undertaken globally needs to be increased if these are to be achieved in a time frame conducive to more rapid mitigation. Without this information there will continue to be debate about the mitigation potential.

Similarly more information is needed about the impacts of animal products on health, the place of meat and milk in diets, and the changes in consumption needed to address these needs. As consumer knowledge increases it is likely that market forces will effect the necessary changes, but this is likely to be at a slower pace than required to address the climate change issues.

In the face of these issues, governments will need to make decisions on priority sectors to mitigate. Adjustments in livestock production to mitigate GHGs will likely involve a combination of consumption, productivity and regulatory measures. It is not inconceivable to consider a scenario in which the wider role of livestock in global development receives greater weighting than its impact on GHG emissions in setting mitigation targets. Other sectors, not so important to global food scarcity, would be called on to contribute more to climate change mitigation.

In the meantime the difficult task of reducing livestock's long shadow must proceed in the face of imperfect information, but in the knowledge that R&D will provide increasingly useful solutions that will eventually achieve the outcomes we desire. Progress can be made, albeit more slowly than many believe to be desirable.

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