Livestock Production

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11 Livestock

Richard Eckard, Matthew Bell,
Karen Christie, Richard Rawnsley

Livestock production is the farming of domesticated terrestrial animals to produce food, fibre and labour. Livestock occupy almost one-third of the ice-free terrestrial land surface of the globe and are an integral part of human history, providing multiple benefits beyond the obvious supply of food and fibre. In many parts of the world livestock are also culturally embedded into the social fabric of society, from being used as a banking system in Africa through to being a religious symbol in India.

According to the United Nations Food and Agricultural Organization (FAO), livestock contribute approximately 12.9% of global calories and 27.9% of global protein consumed. Livestock are also a vital source of employment in rural areas and developing countries, providing food, a source of power for draught, ploughing for crops and transport through to providing clothing products. However, there are also numerous examples of severe and increasing environmental degradation from livestock overgrazing rangelands, nutrient pollution into streams and

waterways from intensive production systems and, more recently, livestock's contribution to climate change. Climate change will also directly impact on livestock health and production. These impacts will require adaptations both in terms of animals and their feed base. In addition to the direct impacts on livestock, climate change will increase competition for land resources for biofuel production, carbon sequestration and crop production.

The United Nations (UN) predicts that global population will reach 9.5 billion people by the middle of the 21st century with approximately 70% of people living in urban areas compared to 50% currently. In alignment with population growth, food demand is also projected to grow by 70% by 2050. However, this growth is predicted to occur predominantly in the developing world (54%), while the developed world is predicted to only grow by 7% over the same time period. While sub-Saharan Africa is predicted to grow by the largest percentage, South and East Asia will be the largest population centres in 2050.

As the majority of population growth will occur in developing countries food security — production, access and affordability — will become an even greater challenge than it is today. A shift in wealth in developing countries and new major growth centres will increase the capacity of a new 'middle class' with the means and desire to move from a predominantly grain-based diet towards one with more animal protein. Thus demand for livestock products is predicted to increase significantly into the future. We may therefore need to accept that livestock will be an integral part of a future food production system globally, but that these systems will need to both adapt to the impacts of and mitigate their impacts on climate change.

Trends in livestock production

By 2050, world demand for all meat sources is projected to increase from 269 million tonnes to 464 million tonnes, with approximately 85% of this demand coming from developing countries. Between 1997 and 2007 global populations of cattle, sheep, dairy cattle, pigs, goats and poultry increased by 4, 5, 12, 13, 20 and 26%, respectively (Figure 11.1). Between 1973 and 2003, meat consumption per capita in developing countries increased by 160% compared to 22% in developed countries. Similarly, milk consumption increased by 55% and 7% in developing and developed countries, respectively.

Future population growth is predicted to occur in developing countries, mainly Africa, India and China, and consistent with current trends, increases in the demand for livestock are likely to be in white meat (fish, pigs and poultry), goats and dairy products (Figure 11.2). Population

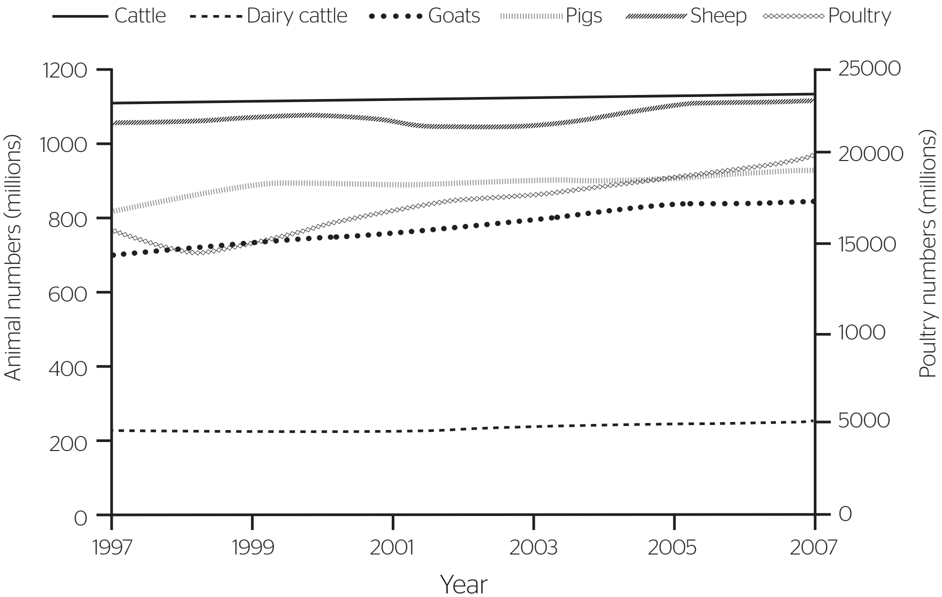

Fig 11.1 Global trends in livestock populations between 1997 and 2007. FAOSTAT 2012

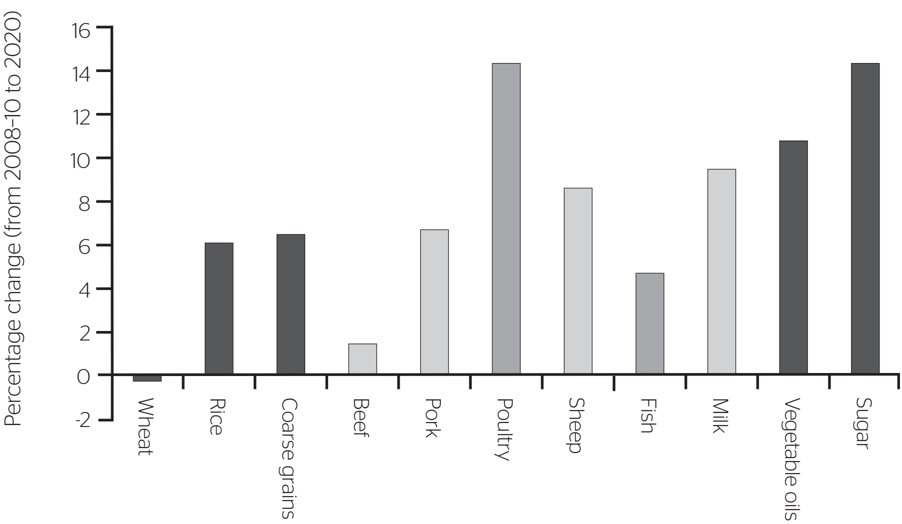

Fig 11.2 Predicted growth in *per capita* consumption of food products (2008–10 to 2020). OECD/FAO 2011

growth, urbanization and income growth will underpin this changing demand for food in developing countries. There is therefore a pressing need to explore adaptation options to accommodate this increasing demand for livestock products in a changing and variable climate whilst developing sustainable approaches to mitigating greenhouse gas emissions.

Impact of increasing temperature and humidity on livestock

Livestock animals are able to maintain a relatively constant and warm body temperature independent of the environmental temperature (i.e. they are homoeothermic). They do this despite widely ranging ambient temperatures by balancing heat production and/or heat loss. Livestock production systems range from cool temperate regions through to warm tropical savannas, as homoeothermic animals have an ability to acclimate to a wide range of latitudes. For example, in Australia the same breed of dairy cow can be found in Tasmania at 43°S and on the Atherton tableland in far north Queensland at 17°S, or even more extreme on the North American continent, in Canada at 53.5°N and in central Mexico at 19°N.

However, despite this ability to flourish across a wide range of climates/environments/altitudes, in a changing climate it is likely that extreme events will have the greatest impact on livestock production. Depending on the severity and duration of such events, animal behaviour, metabolism, feeding activity, immunology and fertility can all be severely impacted. Thermal stress as a result of extreme heat is recognized as a critical problem for livestock production. If the ambient temperature goes above the animal's body temperature, appetite is suppressed and water and mineral requirements increase as the animal tries to maintain its body temperature and becomes heat stressed. This is further exacerbated when heat is accompanied with high humidity. For example, the upper limit of ambient temperatures at which Holstein Friesian dairy cattle maintain a stable body temperature is between 25 and 26°C. At higher temperatures but low relative humidity, the milk yield will decline marginally; but it will decrease by at least a third if humidity is also high.

Thermal stress can be managed through adjusting the animal's environment (e.g. shade, shelter, ventilation in housing systems and access to water), diet manipulation and selection for more heat-tolerant genotypes. In particular, water intake can increase almost three-fold as thermal stress is increased.

In a changing climate, selecting stock suitable for the environmental conditions of a particular region will be important. For example, the Maasai pastoralists in the Mukogodo Division of central Kenya maintain a herd of approximately 90% indigenous stock, mainly African Zebu cattle, east African goats and black-headed Maasai sheep, as they are more resistant to diseases and drought compared to improved livestock breeds.

While genomic selection may provide some assistance, adaptations will need to continue to focus on managing the farm environment. Adaptations to how animals are managed are also likely to be location specific; for example the use of misters may work well in dry and hot environments, where evaporative cooling can be effective, but may be counter-productive in humid and hot environments. Adaptation options might also include a change of species away from poultry, beef cattle and dairy cattle towards goats and sheep, especially for small-scale farmers in developing regions such as Africa.

Extreme events associated with climate change are not limited to heatwaves. Over the past few years there have been livestock deaths from severe drought in areas of Africa and Australia. In recent droughts in Africa, livestock losses were as high as 90% in Tanzania and Kenya during the 2009 drought, while livestock losses were as high as 80% during the 2010 drought in Somalia. Livestock have also drowned in extreme flooding events. For example, major flooding in 1987 and 1988 in Bangladesh, which was reported to be the most severe recorded to that point in time, experienced livestock losses totalling 236,700 while poultry losses totalled 616,000.

Breeding for reduced thermal stress

While differences in thermal tolerance exist between livestock species, there are also large differences between breeds of a species and within each breed. Differences in tolerance to thermal stress between livestock species are primarily due to metabolic heat production and physiological cooling mechanisms, e.g. with *Bos indicus* cattle more able to withstand thermal stress than *Bos taurus* cattle. Form and structural characteristics of livestock species that can help dissipate excess heat and avoid high temperature stress include a large skin area to live-weight ratio, shielded eyes and a light-coloured body. Adaptation to variations in activity level, water and salt availability, feed quality and pests and disease are also beneficial with warmer climates.

Currently in animal breeding the approach of evaluating progeny is largely based on aspects of production, health and fertility traits. This fails to fully account for the effect of environment on different genotypes, and therefore there is potential for better genetic progress to be made with new selection tools. Genetic selection for a rapid growth rate, egg production or high milk production results in animals with high metabolic heat production, without significant changes in their ability to lose heat.

As a result, modern genotypes are more sensitive to heat stress than non-selected or indigenous animals.

Selection of livestock on the basis of resistance to thermal stress has shown a negative correlation with productivity, thus precluding breeding based on the trait to date. However, with the progression of climate change there would come a point where thermal stress is affecting productivity sufficiently to justify future selection on this trait.

Feeding for reduced thermal stress

While animal breeding can lead to permanent and cumulative improvements in biological traits, these genetic improvements are only realized over many years. In contrast, diet manipulation or choosing a breed suited to the feeding system can largely be applied immediately.

Under heat stress, improved production should be possible through modifications of diet composition that either promotes a higher intake by decreasing diet-induced thermogenesis (the increase in energy expenditure above basal fasting level divided by the energy content of the food ingested and is commonly expressed as a percentage — it is, with basal metabolic rate and activity induced thermogenesis, one of the three components of daily energy expenditure), that is low protein or low fibre diets, or compensates the low feed consumption by providing high energy or protein dense diets. In addition, altering feeding management, such as a change in feeding time and/or frequency, are efficient tools to avoid excessive heat load and improve survival rate.

High input production systems tend to rely more on energy-dense diets rather than maximizing forage use, as is the case in low input or more extensive systems (a system of grazing management based on a low carrying capacity on unimproved native pasture without irrigation and usually in areas of medium to low rainfall). These energy-dense diets are likely to result in higher metabolic heat production. The reliance of a high input system on a resource such as bought-in concentrate feed is also vulnerable to price fluctuations, compared to cheaper resources such as pasture, home-grown forage or by-products, which can vary in quality but with a lower overall carbon footprint. On the other hand, low input pasture-based systems are more vulnerable to variable forage quality due to changes in temperature and rainfall than those using blended concentrate feed, or even the conserved forages used in high input systems.

Climate change and disease in livestock

Increasingly humid conditions in tropical latitudes, together with warmer temperatures in temperate latitudes, are likely to increase parasites and disease, especially vector-borne diseases. Also, the prevalence of tropical vectors and diseases moving into temperate latitudes increases. These can include bacterial, fungal and vector-borne diseases, particularly from ticks and mosquitoes. In tropical latitudes, where many of the climate change predictions show increased rainfall and temperature, disease associated with humidity and longer summer seasons are likely to increase. In addition, changes to the seasonal distribution of rainfall and temperature, including extreme climate events, could affect the timing and intensity of pests and disease outbreak. Current understanding of these effects is limited, and thus the ability to predict how these might affect livestock production in future climates is likewise limited. For example in northern Europe ruminant livestock are at increasing risk of vector-borne diseases like bluetongue, a viral disease of cattle and sheep that spread into southern Europe because of recent climate warming in the region giving rise to spread in vector distribution and the appearance of novel vectors.

Climate change and forage production

Temperature, atmospheric CO_2 concentration and precipitation are all critical drivers of forage production and are all likely to be impacted by climate change. Increased atmospheric CO_2 concentration has been shown to increase plant productivity and water use efficiency, as long as other nutrients and water are not limiting growth. However, progressive nitrogen limitation with this increased growth rate may lead to a reduction in forage quality. There are physiological differences between temperate (C3) forages and tropical (C4) forages, in terms of their nutritive feed value, tolerance to higher temperatures and responses to elevated CO_2. Recent modelling in southern Australia has shown a possible trend towards C4 grass dominance in temperate climates, under a range of future climate scenarios (see chapter 9).

Increasing temperature and changing rainfall patterns are likely to influence both the seasonal distribution of forage growth and annual yield. In some regions of the world, positive and negative effects of climate change with respect to forage production may not be geographically far apart. For example, modelling studies in southeastern Australia have predicted reduced pasture yields, as a function of increased temperature and longer drier summers, but increased pasture yields in northwest Tasmania, 450 km further south, largely driven by predictions of warmer winter temperatures and increased summer rainfall. In subtropical and tropical regions, increased temperature may be offset partially by higher CO_2 levels and a longer winter growing season.

Climate change and competition for land for livestock

With an increasing global population placing pressure on land resources, coupled with environmental degradation of existing agricultural land, the number of people per hectare of arable land has been steadily increasing. While the amount of land under agriculture has remained largely static since 1960, the number of people per hectare of arable land rose from 2.4 ha between 1961 and 2000, 4.5 ha between 2000 and 2030 and is predicted to rise to 6.4 ha between 2030 and 2050.

Projected changes in agricultural land availability under future climate scenarios are likely to be regionally specific. Recent analysis of the potential global changes in agricultural land availability shows the total global arable land area is likely to be reduced by 0.8 to 1.7% under an A1B scenario (850 parts per million (ppm) approximate carbon dioxide equivalents by 2100) and increased by 2.0 to 4.4% under a B1 (600 ppm) emission scenario from the IPCC. However, regions of relatively high latitudes may experience an increase of total arable land, while tropical and subtropical regions may suffer varying levels of lost arable land. The United Nations Environment Programme predicts that 25% of the world's food production may become lost due to environmental breakdown by 2050 largely as a result of climate change and where agricultural practices include overgrazing. Collectively this points to an increasing demand on current grazing land and forage production areas, particularly where crop production for direct human consumption is viable, emphasizing the need for improved efficiency and adaptation of livestock systems in future climates.

Impacts of livestock on climate change

The IPCC reports that livestock contribute approximately 15% of global methane (CH_4) emissions and 65% of global nitrous oxide (N_2O) emissions, contributing an estimated 8 to 11% of global anthropogenic greenhouse gas emissions. Global greenhouse gas (GHG) emissions from agriculture were estimated at 6.1 gigatonnes CO_2-e (carbon dioxide equivalent) per year in 2005, with 54% as CH_4 and 46% as N_2O.

The energy and nitrogen losses associated with these greenhouse gasses also represent two of the most significant inefficiencies in livestock production systems. Losses of nitrogen and energy are greater in ruminant production systems (e.g. cattle, sheep, goats) than livestock with a simple single-chambered stomach (e.g. pigs and poultry), with greater gains in breeding for improved feed and energy conversion efficiency having been made in the latter. Thus the challenge for research is to develop technologies and strategies to improve the efficiency of the energy and nitrogen cycles in livestock production, particularly ruminant production systems, leading to more efficient, lower emitting and more sustainable production systems for the future.

A number of options have been reviewed for reducing CH_4 caused by ruminant digestion and N_2O emissions from pastures. Strategies that can be adopted currently include dietary supplementation and management (e.g. feeding fats, tannin, higher quality feeds to reduce methane), balancing energy to protein ratios and applying nitrification inhibitors to pastures to reduce nitrous oxide emissions; these strategies may reduce emissions by up to 20% individually but are also not strictly additive. However, strategies likely to make larger reductions in CH_4 and N_2O loss would include longer term options like breeding for improved efficiency and reduced CH_4 and urinary nitrogen production, and manipulation of microbial populations in the animal and soil, possibly through vaccination, targeted inhibitors, enhanced competition and microbial predation.

The global challenge associated with lowering GHG emissions for livestock production is that most of the livestock are in developing countries (72% of all cattle and 67% of all sheep and goats) and remote rangeland systems of the world, where mitigation practices are unlikely to be a high priority or where regular intervention is not practical. The challenge for wealthier nations is therefore to research and develop mitigation strategies that can be adapted cost-effectively to livestock in remote areas.

Mitigation through reduced livestock consumption

In recent years we have seen numerous popular press and media articles advocating large reductions in greenhouse gas emissions and associated global warming by reducing red meat consumption. The chairman of IPCC, Dr Rajendra Pachauri, was quoted as saying that people should have 'one meat-free day a week if they want to make a personal and effective sacrifice that would help tackle climate change'.

In the developed world there is an increasing awareness of the effects of red meat consumption on both health and environment and reducing red meat consumption is a viable option to reduce one's personal greenhouse gas footprint. However, with the population in the more affluent world predicted to grow by only 7%, relative to the developing world at 56%, a decrease in meat consumption in a small percentage of the developed world will have minimal impact on global meat demand.

The number of people in the world that have the 'privilege' of choosing a vegetarian or vegan diet is therefore extremely limited; and declining, as these are the same people who are choosing to have fewer children. In developing countries, only a small proportion of the population will be wealthy enough to eat red meat. The majority of the increased future global population will rely on locally grown crops and perhaps fish, poultry and pork, as they are unlikely to afford red meat and dairy products. In addition, there are a large number of people in poorer countries who are obligate vegetarians, with only a small amount of grain and maybe milk available. There are large population centres where ruminants are kept for religious reasons (cattle in India, goats in Africa), or as a means of wealth (cattle in Africa) or transport. Strategies that advocate reducing red meat and dairy consumption, while clearly reducing one's personal greenhouse gas footprint, are therefore unlikely to have a major impact on the expected increase in global emissions from agriculture, simply because this choice is limited to a small and relatively affluent portion of the global population who are able to, let alone likely to, adopt this option. With livestock numbers likely to increase in the future, the emphasis must be on research to deliver cost-effective options for reducing the greenhouse gas emissions from a wide range of livestock production systems.

Balancing mitigation and adaptation imperatives

At a global scale, studies have suggested that there are some synergies between mitigation of livestock emissions and adaptation of farming systems to a changing climate. These measures include reducing soil loss, reducing nitrate leaching, managing climate extremes, and avoidance of the cultivation. However, there are a number of examples of conflicts between mitigation and adaption imperatives emerging at more local and regional scales, where logical agricultural adaptation options lead to increased farm greenhouse gas emissions. An example of this would be applying more nitrogen fertilizer in winter, due to increased temperatures and thus growth potential, as an adaptation to hotter and drier summer periods. There is also evidence that some mitigation options, such as increased cropping over grazing, reduce adaptive capacity through increasing risk of crop failure and reduced diversification of income, and that climate change could itself lead to higher livestock emissions and reduced soil carbon increasing soil temperatures.

In livestock production systems, adaptations may include intensification where economies of scale are to be achieved from shade or cooling, but could include making grazing systems more extensive where reduced stocking rates improve the resilience of the system to cope with a larger variability in climate. Clearly some of these options can demonstrate reductions in emissions intensity (greenhouse gas emissions per unit food or fibre produced), while more extensive grazing would reduce emissions per unit area but increase emissions per unit product.

Globally, agricultural CH_4 and N_2O emissions have increased by nearly 17% between 1990 and 2005: an average annual emission increase of about 60 megatonnes (Mt) CO_2-e per year. While total GHG emissions have increased with improvements in livestock productivity, there is some evidence that the GHG emissions per unit of animal product has declined through genetic improvement for most agricultural livestock species (Table 11.1).

Agricultural N_2O emissions are projected to increase by 35 to 60% up to 2030 due to increased nitrogen fertilizer use and increased animal manure production. Likewise livestock-related CH_4 emissions are likely to increase in direct proportion to livestock numbers, predicted to increase by 60% up to 2030. It is therefore clear that net global CO_2-e from agricultural production will increase if global food production targets are to be met, even with a relative reduction in the direct contribution of livestock.

	Methane	**Ammonia**	**Nitrous Oxide**	**Global warming potential$_{100}$**
Chickens – layers	–30	–36	–29	–25
Chickens – broilers	–20	+10	–23	–23
Pigs	–17	–18	–14	–15
Cattle – dairy	–25	–17	–30	–16
Cattle – beef	0	0	0	0
Sheep	–1	0	0	–1

Source: Project for DEFRA by Genesis Faraday partnership and Cranfield University (AC0204).

Table 11.1 Percentage change in greenhouse gas emissions (per tonne product) and global warming potential achieved through genetic improvement (1988–2007).

Livestock as part of the future global food equation

The developed world has a responsibility, with its vast means for investing in technology and innovation, to fund the 'win-win' research required to improve livestock productivity under a warmer and more variable climate while reducing emissions per unit of meat, milk or wool produced. These would need to be innovations that can be adopted by farms in poorer nations as well. Coupled with this research must follow a commitment to share this knowledge. This is the only way in which global food production targets can be met with fewer emissions than are currently predicted.

Humans cannot digest grass and ruminant livestock remain the most efficient means of converting some of the world's extensive grasslands into food for human consumption. Most of the land devoted to extensive livestock production is not viable for crop production. Continual cropping, especially in monoculture, can also lead to reductions in soil carbon, with rotations into perennial pasture one of the only ways to restore soil carbon in the longer term. Likewise, many cropping systems have stubble and residues which can be utilised by incorporating livestock in a mixed farming system. This provides these systems with improvements in biodiversity, resource efficiency and resilience to climate challenges.

We will need to accept that, in a warmer and carbon-constrained future world, where we can produce crops directly for human food consumption this should be the primary goal for agricultural land use. However, removing livestock from the vast rangeland systems of the world will not help the already stringent global food equation. For these systems, research will need to deliver viable, low cost mitigation strategies.

FURTHER READING

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Primary Industries Climate Challenges Centre
The University of Melbourne
Melbourne, Australia, 3010
Email: Richard.Eckard@unimelb.edu.au

A/Professor Richard J. Eckard

Richard Eckard is Associate Professor and Director of the Primary Industries Climate Challenges Centre (www.piccc.org.au), a joint research initiative between the University of Melbourne and the Victorian Department of Primary Industries. He is a science advisor to the Australian, New Zealand and UK governments, and the UN FAO, on climate change adaptation, mitigation and policy development in agriculture. His research focuses on strategies for reducing enteric methane and nitrous oxide from intensive grazing systems, and whole farm systems modelling of climate change adaptation and mitigation strategies in livestock production. Richard has published over 90 scientific publications, holds a number of national and international science leadership roles, being a keynote speaker at numerous industry and international science conferences over the past few years.

Melbourne School of Land and Environment
The University of Melbourne
Melbourne, Australia, 3010
Email: mjbell@unimelb.edu.au

Dr Matthew Bell

Matt Bell is a Postdoctoral Fellow at the University of Melbourne. His research career in the UK and Australia has focused on sustainable farming systems. He has worked in practical and theoretical research on ruminant and monogastric systems. Areas of work include greenhouse gas emissions, climate impacts, breeding, nutrition, health and welfare.

Tasmanian Institute of Agriculture, Private Bag 3502
Burnie, Tasmania, Australia 7320
Email: Richard.Rawnsley@utas.edu.au

Dr Richard P. Rawnsley

Richard Rawnsley is Dairy Centre Leader with the Tasmanian Institute of Agriculture, a joint venture between the University of Tasmania and the Tasmanian Government. Richard has worked with the TIA Dairy Centre for eight years and his main research interests are pasture and forage agronomy, irrigation and nitrogen management, biophysical modelling and farm systems research.

Tasmanian Institute of Agriculture, Private Bag 3502
Burnie, Tasmania, Australia 7320
Email: Karen.Christie@utas.edu.au

Karen M. Christie

Karen Christie is a Project Officer with the Tasmanian Institute of Agriculture, a joint venture between the University of Tasmania and the Tasmanian Government. Karen has over 20 years of experience working in the dairy industry and has substantial expertise in whole farms systems modelling of climate change adaptation and greenhouse gas mitigation strategies in livestock production systems. In recent years, Karen was instrumental in the development of the Australian dairy greenhouse gas inventory calculator DGAS, has published the greenhouse gas emissions of 100 Australian dairy farms, been involved in the pre-gate greenhouse gas emissions assessment of an additional 140 Australian dairy farms and has published climate change adaptation options for Australian livestock industries at various national conferences.