

## **Can livestock production be increased without increasing greenhouse gas emissions?**

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### **ABSTRACT**

More efficient farming practices will increase livestock production without increasing greenhouse gas (GHG) emissions. GHG emissions of methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and carbon dioxide (CO<sub>2</sub>) have always been part of agriculture, but national and international concern about global warming has focused research towards their mitigation. CH<sub>4</sub> production represents a loss of about 9% of metabolisable energy in feed, whilst N<sub>2</sub>O production represents a loss from excessive nitrogen (N) application. Mitigation should therefore provide benefits for farming by conserving dietary energy and reducing fertiliser costs. Unfortunately there are limited options for reducing CH<sub>4</sub> loss. Nevertheless, by ensuring animals are productive and fertile and adopting management systems that ensure a high utilisation of feed grown, it is possible to lower CH<sub>4</sub> emissions per unit of product. There are more opportunities for reducing N<sub>2</sub>O emissions, because these originate in large part from N fertiliser application, and more prudent use will lower costs, minimise nitrate

leaching into waterways as well as lowering GHG emissions. Emissions per unit of product are termed emissions intensity. Application of current and new knowledge to agricultural systems will increase livestock production and lower emissions intensity whilst sustaining our ecosystem, but farmers will always need to address environmental issues.

**Keywords:** greenhouse gases; livestock; methane; emissions intensity.

## INTRODUCTION

The measurement and mitigation of greenhouse gas (GHG) emissions is a recent priority for agricultural research, driven as much by politics and trade as by a need to “save the planet”. Farmers affected by GHG legislation should consider the drivers for GHG reduction as opportunities for minimising waste. These include dietary energy loss to ruminant methane (CH<sub>4</sub>) production, excessive dietary nitrogen (N) intakes wasted in urine, which are responsible for nitrous oxide (N<sub>2</sub>O) emissions, and the loss of soil organic matter to carbon dioxide (Pinares-Patiño *et al.*, 2009). Reducing energy waste, N application and organic matter losses may be easier for farmers to accept than a taxation for creating gasses that are both invisible and have always been associated with agriculture. These GHG emissions are indisputable, but emissions beyond the farm gate may be as large as those on

farm (Gill *et al.*, 2010), associated with energy costs of transport, processing, packaging, refrigeration and waste by consumers.

The prime purpose of agriculture is production of food for people, which will increase as the global population increases, and feeding the population will incur environmental costs. These include replacement of “natural” ecosystems with intensive farming, and the interventions required to manage highly productive land such as herbicides, insecticides, fertiliser, genetically engineered forages, irrigation, extensive use of machinery and transport, for example. The reward is food, whether it is grains, vegetables, fruits or animal products. A focus on GHG mitigation must never be allowed to dominate the most fundamental of human needs – food. This is increasingly recognised in international discussions, and global agricultural GHG mitigation is moving from a need to reduce total emissions,

which is only a small part of the total (Table 1), to a reduction in emissions intensity (Ei) associated with food production. Ei is a measure of GHG emissions associated with food production. This is good for agriculture, because efficient production systems usually reduce Ei and are also the most profitable for farmers.

The ongoing challenge is to maintain agricultural profitability, and if the GHG debate is viewed as a need to increase production efficiency and to reduce wastage, this becomes an acceptable objective. However, it is also important to distinguish between production efficiency involving aspects such as high pregnancy rates, twinning in sheep, and high survival of progeny, as well as rapid liveweight gain or high milk production, and the consequences of high levels of intensive production. For example, very high production/ha may require high stocking rates, excessive application of fertiliser and importation of feeds. These can damage both land and environment (Mackay, 2008). Such environmental damage has been illustrated in the Rotorua and Taupo catchments, where excessive N run-off from adjacent dairy farms has lowered water quality (Ledgard *et al.*, 2007). The balance between production and efficiency is complicated, driven by

**TABLE 1:** Annual emissions of the principal GHGs in New Zealand, United States and globally. Values are expressed in CO<sub>2</sub>-equivalents. New Zealand and USA agriculture estimates exclude CO<sub>2</sub> emissions. ND = Not determined.

Parameter	Percentage of total			Tonne/human <sup>1</sup>		
	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>
Total emissions						
New Zealand <sup>2</sup>	34.6	16.0	48.3	6.00	2.77	8.39
USA <sup>3</sup>	8.2	4.6	85.1	1.90	1.00	19.10
Global <sup>4</sup>	14.3	7.9	76.7	0.96	0.52	4.63
Agricultural contributions to total						
New Zealand <sup>2</sup>	90.6	96.0	ND	5.44	2.66	ND
USA <sup>5</sup>	45.0	55.0	ND	0.62	0.75	ND
Global	54.3	45.7	ND <sup>6</sup>	0.45	0.38	ND

<sup>1</sup>Assumes a New Zealand population of 4.3 million and a global population of 6.88 billion.

<sup>2</sup>New Zealand 2008 inventory (Ministry for the Environment, 2010).

<sup>3</sup>United States GHG Inventory 2008 Executive summary (United States Environmental Protection Agency, 2010a).

<sup>4</sup>Global mitigation of non-CO<sub>2</sub> greenhouse gases in year 2000, Technical summary (United States Environmental Protection Agency, 2010b).

<sup>5</sup>GHG Inventory 2008, Agriculture (United States Environmental Protection Agency, 2010c).

<sup>6</sup>Global calculations of agricultural CO<sub>2</sub> emissions (Mt CO<sub>2</sub>-e) were 7631, 3113 and 2616 for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O, respectively, but have been excluded from these data for consistency.

costs and returns. Farmers need to be aware that restrictions may be placed on inputs, as in the Netherlands, if the drive for production damages the land and environment.

## THE GREENHOUSE GASES

Agricultural GHGs are: CH<sub>4</sub>, identical to coal gas or marsh gas; N<sub>2</sub>O, which is the same as laughing gas, or nitrous (NOS) as used in drag racing; and carbon dioxide (CO<sub>2</sub>), which is produced by animals, used by plants and is the principle product of soil organic matter loss. Table 1 summarises the contribution of these GHGs on a global basis and from New Zealand. When expressed on a per person basis, New Zealand values rank amongst the top in the world (United States Environmental Protection Agency, 2010b), largely because we have a small human population and a high animal population – which feeds a lot more people than our 4.3 million.

GHG accounting uses the term CO<sub>2</sub> equivalents (CO<sub>2</sub>-e). This is because gases differ in their contribution to global warming or their global warming potential (GWP). To convert values for CH<sub>4</sub> to CO<sub>2</sub>-e, each kg of CH<sub>4</sub> is multiplied by 21. In other words, one kg CH<sub>4</sub> has a GWP of 21 kg CO<sub>2</sub>. The multiplier for N<sub>2</sub>O is 310, so 1 kg N<sub>2</sub>O has a GWP of 310 kg CO<sub>2</sub>. The CO<sub>2</sub>-e terminology simplifies GHG accounting.

Globally, agriculture accounts for 9-14% of GHG emissions as calculated from total CH<sub>4</sub> and N<sub>2</sub>O emissions and the percentages from agriculture in Table 1. In contrast, New Zealand agriculture accounts for 48% of our total GHG emissions, of which 34% is CH<sub>4</sub> and 16% is N<sub>2</sub>O (Ministry for the Environment, 2010a).

CO<sub>2</sub> from agriculture is not counted in emissions unless there is a change of land use. For example, felling a forest to establish a farm causes a substantial carbon loss from the trees. Similarly, carbon accumulation or loss from soil is ignored, and although claims have been made that suggest pastoral farmers are mitigating GHG emissions through soil organic matter accumulation, this is unlikely to be the case (Schipper *et al.*, 2007) and any loss of organic matter represents carbon loss to the atmosphere.

A true assessment of GHG emissions should include all inputs based on life cycle analysis (LCA). Examples might include the emissions from animals, fertilisers, fertiliser manufacture, soil organic matter loss, herbicide and pesticide manufacture and application, fuel, energy used in smelting iron ore and manufacturing to build farm machinery, electricity generation, associated with

buildings, and so on. This is an increasingly common approach, but the choice of variables included, and not included in a LCA, can have large effects on predictions. More recently LCA have been extended to food processing beyond the farm gate. These analyses offer good potential for identifying options to further reduce E<sub>i</sub> (Leslie *et al.*, 2008).

## MITIGATING GHG ON FARM

### Methane (CH<sub>4</sub>) mitigation

The average adult sheep, deer, beef and dairy cow produces 11, 22, 57 and 77 kg CH<sub>4</sub>/annum, respectively (Ministry for the Environment, 2010), but values vary widely, depending on feed intakes and the level of production. The New Zealand inventory is calculated from animal numbers and production x intakes x CH<sub>4</sub> yield (g/kg feed dry matter intake (DMI)). Current values are about 20-21 g CH<sub>4</sub>/kg DMI for sheep and cattle (Ministry for the Environment, 2010). Emissions are not affected to a significant extent by forage type, but yield declines by about 3-5g CH<sub>4</sub>/kg DM intake for each multiple of maintenance increase in intake (Muetzel *et al.*, 2009; Hammond *et al.*, 2011). So, contrary to previous suggestions (Waghorn & Woodward, 2006), changing forage species is unlikely to have a significant effect on CH<sub>4</sub> yield, but forages that enable high intakes and fed *ad libitum* will have a lower CH<sub>4</sub> yield (g CH<sub>4</sub>/kg DMI) compared to similar forages fed at low intakes. High intakes also result in high levels of production, and are usually associated with greater profitability.

Many dietary additives have been suggested for mitigating CH<sub>4</sub>, but few have a persistent effect, especially with forage feeding. For example, monensin may lower CH<sub>4</sub> yield when grain based diets are fed, but effects are variable and often non-existent when pasture is fed (van Vugt *et al.*, 2005). Addition of oils to diets may lower CH<sub>4</sub> yields (Grainger & Beauchemin, 2011), but this is impractical under extensive grazing, and the effects of condensed tannins (Grainger *et al.*, 2009) need to be confirmed by repeating measurements using respiration chambers. Other options have been summarised in several reviews (Pinares-Patiño *et al.*, 2009; Buddle *et al.*, 2010; Eckard *et al.*, 2010; Hook *et al.*, 2010; Martin *et al.*, 2010) and include removal of protozoa or vaccination, but these are not feasible at present, and most options are either too expensive or not feasible. Small reductions in CH<sub>4</sub> emissions from ruminants may be possible, but any treatment must be profitable and be applicable to grazing animals, many of which graze hill country so routine supplementation is often impractical.

Some individual animals appear to have a lower CH<sub>4</sub> yield (g CH<sub>4</sub>/kg DMI) than others (Pinares-Patiño *et al.*, 2009). Selection for this trait could lower emissions. However, farmers would need incentives to select low emitters in preference to productivity, fertility, disease resistance, or other traits that are relevant to them. It is also important that the trait of low emissions is persistent, heritable, unaffected by diet and that these individuals use feed efficiently and have high levels of production.

#### Nitrous oxide (N<sub>2</sub>O) mitigation

N<sub>2</sub>O on a farm arises primarily from excess N not taken up by plants in urine spots and also from N fertiliser applications, especially in anaerobic (wet) conditions (de Klein & Eckard, 2008). Thus, any strategy lowering the dietary N concentration will reduce N<sub>2</sub>O emissions. Application of N fertilisers on the basis of plant requirements, and an overall reduction, especially in autumn, will lower N<sub>2</sub>O emissions and nitrate losses to ground water, as well as reduce costs. Emissions are exacerbated by wet conditions and when stock pug wet pastures, so that stand-off pads will lessen N<sub>2</sub>O emissions as

well as maintain herbage quality. Another option is the application of nitrification inhibitors to pastures, and possible use as a slow release intra-ruminal bolus (Ledgard *et al.*, 2008). In their evaluation of current mitigation technologies, de Klein and Eckard (2008) concluded a reduction of 15% in N<sub>2</sub>O emissions from grazing systems was possible, and although reduced fertiliser application would reduce costs, use of nitrification inhibitors may increase costs.

#### Carbon dioxide (CO<sub>2</sub>) mitigation

Although CO<sub>2</sub> emitted directly from farms is not usually included in an inventory, good farming practice that limits conventional soil cultivation, such as by using direct drilling (Gregorich *et al.*, 2005), or removing stock from very wet soils (de Klein & Eckard, 2008) has multiple benefits. These include, maintaining soil organic matter, protecting pastures from pugging damage, and lessening the need for pasture renewal. Even intensive pastoral grazing without cultivation, can result in organic matter losses (Schipper *et al.*, 2007), with the lost organic matter contributing to atmospheric CO<sub>2</sub>.

**TABLE 2:** Opportunities for altering GHG emissions intensity (Emissions/unit of production) from forage based ruminant production systems.

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#### ANIMAL OPTIONS

- Species – sheep beef, dairy – all have a similar CH<sub>4</sub> yield but different productivity.
- Age or maturity – affects energy partitioning to production and carcass composition.
- Genetic potential – residual feed efficiency, selection for profitable traits.
- Environmental adaptation – productive and reproductive resilience; good grazers; seek out feed and water, even if substantial walking is needed. Some have an inherent resilience with low susceptibility to diseases such as ticks and internal parasites, and avoid toxic forages.

#### FARM SYSTEM OPTIONS

**Extensive grazing** – options often dictated by needs for sustainability and need to accommodate adverse conditions (feed supply) with minimal inputs.

- Provision of pastures to match animal energy and nitrogen requirements.
- Use of tested sires to maximise birth rate, survival and weaning weight.
- Pregnancy scanning and removal of non-pregnant females.
- Seasonal supplementation of females to ensure return to service and adequate feeding of progeny to minimise time to slaughter or mating.
- Manage for minimal parasite impact.
- Good mothering and high weaning rate; good growth rates.

**Intensive grazing**- use of improved forages, adequate feed supply, ability to supplement and manage to achieve a high production/ha.

- Production affected by forage type and management to maximise harvest of herbage.
- Optimal forage species to maximise feeding value.
- Use of additives, rumen modifiers and supplements to ensure adequate feeding at all times.
- High reproduction, early mating, high conception and weaning rates.
- Attendance to health, good longevity to minimise replacement rate.
- Select animals that are adapted and have good genetic merit under forage grazing.
- Remove animals from waterlogged pasture.
- Avoid excess fertiliser; possible use of nitrification inhibitors.

**Intensive feedlot** – for dairy production or finishing for carcass production.

- Optimal ration formulation and adaptation to finishing ration.
  - Appropriate parasite and disease control.
  - Avoidance of heat stress by providing shade/sprinklers as appropriate.
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## LOWERING EMISSIONS INTENSITY – EFFICIENT FARMING

Good farming practice is efficient, profitable, and will lower GHG emissions per unit of food production. A range of opportunities for lowering  $E_i$  on-farm is summarised in Table 2. Although choice of animal species will not affect  $CH_4$  yield (g  $CH_4$ /kg DMI) the productivity of different species in terms of milk production from dairy cows versus trimmed cuts from sheep, have a significant effect on  $E_i$ . Emissions intensity is also reduced when a high proportion of feed intake is directed toward production, with less to maintenance, ideally determined over a lifetime, and is affected by factors such as age at calving, lambing or fawning, reproductive success (weaning percentage) and longevity, as well as resistance (or susceptibility) to disease, and parasitism. For example, Casey and Holden (2005) predicted the use of fewer, but higher producing dairy cows, along with the removal of non-milking individuals, could reduce GHG emissions by 28-33%.

The impact of feed intake, quality and production is illustrated in Table 3, where increasing the daily liveweight gain of lambs from 100 to 300 g/day reduced  $E_i$  from 285 to 88 g  $CH_4$ /kg gain, mainly because a higher proportion of feed energy was directed to production, rather than maintenance. The reduction in  $E_i$  with high animal growth rates will also result in lower total emissions, because sheep will reach slaughter weight in less time than those with lower rates of liveweight gain. Similar calculations have been made for beef cattle systems in Australia by Hunter and Neithe (2009). They showed a 30% reduction in  $CH_4$  emissions would be possible by either increasing the calf weaning rate from 65% to 85%, or by increasing the cattle rate of liveweight gain at pasture from 0.3 to 0.6 kg/day. These improvements would decrease  $E_i$ , but overall emissions would be unchanged, because cattle numbers would increase to take advantage of available pasture. Similarly,  $E_i$  from sheep meat will be lower for twin lambs than singletons because ewe maintenance emissions are halved.

**TABLE 3:** An example of reductions in methane emissions intensity ( $E_i$ ;  $CH_4$ /kg liveweight gain) brought about by improving feed quality and intakes of ram lambs fed ryegrass pasture. ME =Metabolisable energy; MJ = Mega joules;  $CH_4$  = Methane; DM = Dry matter; DMI = DM intake; M = Maintenance level of intake;  $E_i$  = Emissions intensity.

Diet ME (MJ/kg DM)	Daily gain (g)	Daily intakes <sup>1</sup>		$CH_4$ (g/kg DMI)		DMI (kg/kg gain)	$E_i$ (g/kg gain)
		ME (MJ)	kg DM	At M <sup>2</sup>	Actual <sup>3</sup>		
10.0	0	8.8	0.88	24.0	24.0	∞	∞
10.0	50	10.9	1.09	24.0	24.0	21.8	520
10.0	100	12.9	1.29	24.0	22.1	12.9	285
11.0	200	15.5	1.41	22.0	19.4	7.1	137
12.0	300	17.3	1.44	21.0	18.4	4.8	88
12.5	350	19.0	1.52	21.0	18.0	4.3	78

<sup>1</sup>Based on energy requirements for a 40 kg young ram lamb (Nicol & Brookes, 2007).

<sup>2</sup>Methane produced by a sheep eating sufficient feed to maintain itself.

<sup>3</sup>Actual methane emissions based on values for maintenance but reduced by 6.3g/kg DMI above 1.2xM (Hammond *et al.*, 2011).

**TABLE 4:** Emissions, expressed as  $CO_2$ -e, associated with production of foods for human consumption in the United Kingdom.

Food	Type of emissions (g/kg product)			Emissions expressed as $CO_2$ -e (kg)		
	$CH_4$	$NH_3$	$N_2O$	kg product	MJ edible product	kg edible protein
Milk	19	3	1	1.0	0.37	28.6
Eggs	8	28	4	3.8	0.57	33.3
Chicken meat	5	23	3	3.5	0.40	18.4
Pork	49	28	2	4.7	0.30	34.2
Beef	265	71	12	14.7	1.40	93.5
Sheep meat	301	41	11	15.8	1.51	92.9

Derived from Department of the Environment, Food and Rural Affairs (2008) and Gill *et al.*, (2010)

Animal genetic merit affects the potential level of production, but productivity can be complemented by identification of individuals that require less feed for maintenance and production than the population average (Herd & Arthur, 2009). Within a population there is a range in energy requirements for animals of a similar size and production, and selection for efficient and inefficient individuals is referred to as residual feed intake (RFI), net feed intake, or sometimes feed conversion efficiency. Identification of efficient individuals has been carried out for pigs, poultry, beef cattle, and more recently dairy cows. Efficient cattle require 10% less feed than the population average (Waghorn & Hegarty, 2011) and lower intakes result in less CH<sub>4</sub> and N<sub>2</sub>O production, thus reducing E<sub>i</sub>.

### A FARM SYSTEMS APPROACH

Farm systems represent an integration of technologies for animal production. Animal efficiency should be complemented with efficient feed production and utilisation, so that sufficient feed is always available to capitalise on the animal's genetic potential, while at the same time waste is minimised, as with efficient grazing management. Prudent fertiliser use will lessen fertiliser costs whilst maintaining pasture production. New Zealand pastures contain excessive N, relative to animal requirements, and this is both detrimental for the environment and also reduces the efficiency of feed utilisation (Pacheco & Waghorn, 2008). Combining best practice for pasture production and utilisation with optimal animal selection and management will result in profitable and productive farming with a low GHG E<sub>i</sub>.

These concepts involving animals, pasture and fertiliser, are part of normal farm management, but this simple recipe is affected by climatic variability, production costs, and changing prices received from sales. Ideally, livestock should be insulated from climatic effects. This may be achieved through irrigation, importation of feed from within or outside of New Zealand, and provision of stand-off pads or barns in some regions. All of these options generate GHG, whether it is from the manufacture of steel for buildings, generation of electricity or cultivation, harvesting and transport of supplementary feed. An honest appraisal of GHG emissions should take these, and other, factors into account when computing total emissions as well as E<sub>i</sub>. This is best achieved by simulation modelling or LCA.

Recently Beukes *et al.* (2010b) undertook a modelling assessment of New Zealand dairy systems, and suggested a reduction of about 30% in GHG emissions was possible through reduced replacement rates, improving feed quality, reducing

fertiliser applications, lowering dietary N concentration by including maize silage in the diet, and using efficient cows with a high genetic merit. The benefits of each of these modifications had previously been demonstrated on farm, but individually, rather than in combination. Although their model demonstrated good potential for mitigating GHG whilst maintaining production, these are only predictions and investment must be provided to evaluate model predictions for mitigating emissions from dairy and other systems on farm. Predictions are only as good as the assumptions upon which they are based, and unfortunately assumptions are often taken as fact, even when this was not the intention of the author(s). Furthermore, gains in efficiency by good management are likely to result in increased stock numbers, especially when a feed surplus is generated, and thus potentially increasing total GHG emissions.

### RUMINANTS AS FOOD PRODUCERS

New Zealand ruminants produce nutritious food from forages that humans cannot eat. Our farming systems differ from feeding systems in many parts of the world where grains comprise 20-40% of dairy diets and up to 90% of the diet for beef finishing in North America. Ruminants do not require grain, which is better fed to monogastric species that cannot utilise forages, such as pigs, poultry and humans. Gill *et al.* (2010) calculated efficiencies of feed energy conversion, based on diets comprising forages with concentrates, into edible product, with efficiencies of about 0.25, 0.06, 0.21 and 0.20 for milk, beef, pork and poultry meat, respectively. The data were calculated for the USA feeding system, and also for South Korea, and beef production was always least efficient, even though the USA beef system was grain based where as that in South Korea was largely forage based. Dairy cows captured dietary energy in milk with a similar efficiency as pigs and poultry, and forage feeding provided an additional benefit because grains were not required to create a high quality and nutritious food.

The GHG E<sub>i</sub> associated with animal production systems is summarised in Table 4. When expressed on an energy basis for edible products, the relativity of dairy cows, beef cattle, pigs and poultry are similar to their energetic efficiencies. It is important that E<sub>i</sub> is used sensibly on an energy or protein basis, rather than expressed in terms of milk which is about 88% water, whilst carcass includes bone and fat that are not eaten. There are many opportunities to use data in ways that meet the needs of authors or funders, creating confusion for the readership.

Feeding decisions for ruminants are driven largely by feed availability and return on

investment. As long as it is profitable, grain will be included in ruminant diets in many countries, and the use of palm kernel expeller in New Zealand is no different. Although beef and sheep meat are associated with a high  $E_i$ , as long as consumers pay the price, production will be ongoing. However, if mitigation of GHG from agriculture became a high priority, only dairy animals would be retained to graze pastures, and our diets would be dominated by vegetables and grains (Waghorn & Hegarty, 2011) with pork and chicken.

### CONCLUSION

Although agriculture accounts for only 9-14% of global GHG, within New Zealand it accounts for about 48% of our total emissions, and we are obligated to reduce these. Consensus amongst researchers suggests reductions in both  $CH_4$  and  $N_2O$  yields (g/kg DMI) are unlikely to exceed 15-20%, but  $E_i$  can be reduced substantially whilst

retaining or increasing profitability, by farming efficiently. This can be achieved by adoption of best practice for feed production, utilisation and animal aspects of farming. Efficient farming will maintain food production, but what processes will be required for measuring compliance? Farmers are likely to be faced with increased legislation to ensure environmental sustainability. This may include some form of GHG accounting. Farmers and industry leaders need to work with policy makers to ensure their views are heard and to influence decisions, rather than reacting to legislation drafted by persons with limited knowledge of farming. More efficient farming can increase livestock production without increasing GHG emissions. This will be good for farmers, governments and especially people, because we all need food and have a right to choose food that we like.