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Allocation will be on an "intensity" basis, meaning participants receive an allocation that is linked to their output. The assistance level will start at 90% of the sector's emissions baseline and will phase out at 1.3 percent per annum from the previous year's allocation, starting in 2016. The emissions baseline is yet to be established but will be the industry average of emissions per unit of output in a chosen year or combination of years.

The calculation for allocation is as follows:

Allocation = Output x Allocative baseline x Assistance level

The allocation will be uncapped, meaning that there is no set limit on the number of NZUs that may be allocated and each participant will receive the 90% allocation.

Allocating NZUs to participants is a mechanism that could substantially alter the impact of the NZETS. There are numerous different methodologies for allocating NZUs and different methodologies place different incentives onto the emitter (Ministry of Agriculture and Forestry, 2009a). For example, using a fixed methodology that establishes a fixed level of NZUs to allocate means the marginal cost of increasing emissions, or production, is the same as the cost of CO_2-e. This is effectively establishing a GHG emissions cap. Conversely, an intensity based system fluctuates with production and therefore GHG emissions', meaning the marginal cost of increasing emissions remains the same. Take a company that produces 100 tonnes of CO_2-e in 2015. Under a fixed system assuming they get 90% of 2010 emissions, which are 100 tonnes and the price of carbon is $20 per tonne. Under an intensity system they receive 90% of emissions. Under both systems the company would receive 90 units in 2015 so the liability is 10 units, or 10 x $20 = $200 worth of liability. What are the implications if the company increased their emissions to 150 tonnes of CO_2-e in 2016? Under the fixed system they would receive 90 units and they would have a liability of 60 units, or 60 x $20 = $1,200. In contrast, under an intensity based system they would receive 135 units and the liability would remain at 10%, so would be 15 units or 15 x $20 = $300 worth of liability. A stronger incentive to reduce emissions exists under a fixed system, compared to an intensity based system.

The Government has agreed to an intensity based system to help transition the agriculture sector to a low carbon economy at a rate that is sustainable. An intensity based system does not necessarily discourage increasing production; instead it encourages more efficient production.

CONCLUSION

Agriculture's inclusion in the NZETS has not been without its challenges. However, the settings within the NZETS on how liabilities are calculated can still incentivise behaviour on-farm to better manage GHG emissions. The inclusion of agriculture in the scheme is part of the Government's approach to environmental sustainability on-farm for climate change. The NZETS will affect all aspects of agriculture and therefore will have a significant impact on the behaviour of the sector. Incentives are likely to develop over time with refinement of the NZETS for agriculture and other sectors and with changes in farming practices.

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_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) have always been part of agriculture, but national and international concern about global warming has focused research towards their mitigation. CH_4 production represents a loss of about 9% of metabolisable energy in feed, whilst N_2O 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_4 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_4 emissions per unit of product. There are more opportunities for reducing N_2O 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_4) production, excessive dietary nitrogen (N) intakes wasted in urine, which are responsible for nitrous oxide (N_2O) 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_2-equivalents. New Zealand and USA agriculture estimates exclude CO_2 emissions. ND = Not determined.

Parameter	Percentage of total			Tonne/human[1]		
	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2
Total emissions						
New Zealand[2]	34.6	16.0	48.3	6.00	2.77	8.39
USA[3]	8.2	4.6	85.1	1.90	1.00	19.10
Global[4]	14.3	7.9	76.7	0.96	0.52	4.63
Agricultural contributions to total						
New Zealand[2]	90.6	96.0	ND	5.44	2.66	ND
USA[5]	45.0	55.0	ND	0.62	0.75	ND
Global	54.3	45.7	ND[6]	0.45	0.38	ND

[1]Assumes a New Zealand population of 4.3 million and a global population of 6.88 billion.

[2]New Zealand 2008 inventory (Ministry for the Environment, 2010).

[3]United States GHG Inventory 2008 Executive summary (United States Environmental Protection Agency, 2010a).

[4]Global mitigation of non-CO_2 greenhouse gases in year 2000, Technical summary (United States Environmental Protection Agency, 2010b).

[5]GHG Inventory 2008, Agriculture (United States Environmental Protection Agency, 2010c).

[6]Global calculations of agricultural CO_2 emissions (Mt CO_2-e) were 7631, 3113 and 2616 for CO_2, CH_4 and N_2O, 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_4, identical to coal gas or marsh gas; N_2O, which is the same as laughing gas, or nitrous (NOS) as used in drag racing; and carbon dioxide (CO_2), 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_2 equivalents (CO_2-e). This is because gases differ in their contribution to global warming or their global warming potential (GWP). To convert values for CH_4 to CO_2-e, each kg of CH_4 is multiplied by 21. In other words, one kg CH_4 has a GWP of 21 kg CO_2. The multiplier for N_2O is 310, so 1 kg N_2O has a GWP of 310 kg CO_2. The CO_2-e terminology simplifies GHG accounting.

Globally, agriculture accounts for 9-14% of GHG emissions as calculated from total CH_4 and N_2O 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_4 and 16% is N_2O (Ministry for the Environment, 2010a).

CO_2 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 Ei (Leslie *et al.,* 2008).

MITIGATING GHG ON FARM

Methane (CH_4) mitigation

The average adult sheep, deer, beef and dairy cow produces 11, 22, 57 and 77 kg CH_4/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_4 yield (g/kg feed dry matter intake (DMI)). Current values are about 20-21 g CH_4/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_4/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_4 yield, but forages that enable high intakes and fed *ad libitum* will have a lower CH_4 yield (g CH_4/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_4, but few have a persistent effect, especially with forage feeding. For example, monensin may lower CH_4 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_4 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_4 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_4 yield (g CH_4/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_2O) mitigation

N_2O 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_2O emissions. Application of N fertilisers on the basis of plant requirements, and an overall reduction, especially in autumn, will lower N_2O 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_2O 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_2O emissions from grazing systems was possible, and although reduced fertiliser application would reduce costs, use of nitrification inhibitors may increase costs.

Carbon dioxide (CO_2) mitigation

Although CO_2 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 & Eckhard, 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_2.

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

ANIMAL OPTIONS

- Species – sheep beef, dairy – all have a similar CH_4 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.

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 Ei 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 Ei. 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 Ei 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 Ei 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 Ei, but overall emissions would be unchanged, because cattle numbers would increase to take advantage of available pasture. Similarly, Ei 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 (Ei; 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; Ei = Emissions intensity.

Diet ME (MJ/kg DM)	Daily gain (g)	Daily intakes[1]		CH_4 (g/kg DMI)		DMI (kg/kg gain)	Ei (g/kg gain)
		ME (MJ)	kg DM	At M[2]	Actual[3]		
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

[1]Based on energy requirements for a 40 kg young ram lamb (Nicol & Brookes, 2007).
[2]Methane produced by a sheep eating sufficient feed to maintain itself.
[3]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 Affair (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_4 and N_2O production, thus reducing Ei.

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 Ei.

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 Ei. 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 Ei 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 Ei 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 Ei, 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 Ei 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.

The role of breeding in reducing sheep GHG intensity

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ABSTRACT

Historic and potential future greenhouse gas (GHG) emission reductions resulting from genetic selection decisions in sheep have been quantified. Historic genetic trends in number of lambs born in maternal breeds and growth in terminal sire breeds were estimated to have reduced GHG emissions per kilogram of lamb carcass weight by 0.45% and 0.09% per year of genetic change, respectively. The implications of future selection using different indexes were also examined. Selection based solely on farm profits could lead to emission reductions per unit of product by 0.185 kg CO_2-e/kg carcass weight, or a 0.59% reduction in lamb carcass weight emissions per annum. Selection of sheep ignoring profit and solely targeting reduced GHG emissions per kilogram of lamb carcass weight could lead to emission reductions of 0.242 kg CO_2-e/kg lamb carcass weight, equivalent to a 0.77% reduction in total emissions per annum. However, doing this would come at a cost of 26.6 cents per breeding ewe reduction of 23.7% per annum in annual genetic progress. An alternative index that provides a balance between reducing GHG emissions and improving farm profits was estimated to produce an annual 0.193 kg CO_2-e/kg carcass weight or a reduction of 0.62% reduction in emissions per annum in GHG emissions with minimal sacrifice in genetic improvement of farm profitability.

Keywords: greenhouse gases; sheep; genetic selection.

INTRODUCTION

In the past, genetic improvement goals in New Zealand have generally focussed on improving traits which add to farm profit. As a consequence, the productivity of the New Zealand sheep industry has increased significantly. For example, the number of lambs born (NLB) breeding value (BV) increased 5 percentage points between 2000 and 2006 in performance recorded sheep participating in the Sheep Improvement Limited - Advanced Central Evaluation (SIL-ACE) national genetic evaluation analysis. In the same analysis, the average lamb carcass weight BV increased by 0.9 kg (Young & Amer, 2009).

With agriculture potentially becoming part of the emissions trading scheme in New Zealand, farmers may in the future be incentivised to apply technology that reduces greenhouse gas (GHG) emissions while still improving farm profitability. A