Sweetening the deal – High sugar grasses in Reducing New Zealand's Agricultural Greenhouse Gas Emissions

Nigel Taptiklis

Environmental Studies, School of Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington, New Zealand. Email nigel.taptiklis@gmail.com

Abstract

Globally the loss of nitrogen (N) into the environment due to agricultural activities threatens human and ecosystem health. N is essential for plant growth and since 1990 New Zealand's (NZ) agricultural sector has greatly increased N fertiliser use, resulting in high protein pasture. However ruminant conversion efficiency of dietary protein into products reduces with higher protein intake, and excess nitrogen is excreted in urine. Animal urine is the primary source of the greenhouse gas (GHG) nitrous oxide (N_2O) from grazed pasture soils. Perennial ryegrass *(Lolium perenne)* cultivars have been selectively bred to increase water soluble carbohydrate (WSC) content. A literature review into the effects of these high sugar grasses (HSG) on ruminants was conducted to assess whether HSGs would be cost effective in reducing NZ's N_2O emissions. Converting NZ's dairy pasture to HSGs would cost \$2.8 million per year and reduce \$25.6 million worth of N_2O emissions annually (\$30 tonne CO_2 equivalent). Modelling of factors affecting the ratio of WSC to crude protein (CP), and of the effect of WSC to CP ratio on urine N, is recommended to enable GHG inventory calculations and nutrient budgeting. Additionally the WSC to CP ratio of pasture is a major factor affecting N excretion by ruminants and should be incorporated into GHG inventory calculations.

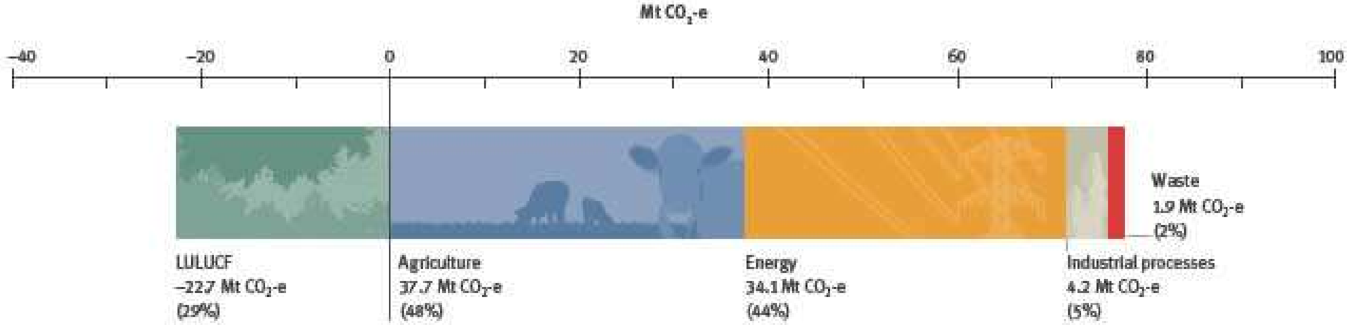
Keywords: Lolium perenne; high sugar grass; water soluble carbohydrate; nitrogen; nitrous oxide.

Introduction

It has been claimed that 60% of all New Zealand's (NZ) emissions reductions that could be achieved for less than \$30 per tonne (carbon dioxide equivalent) are agricultural, and that certain emission reduction methods can actually increase farm profits (New Zealand Herald 23/07/08). However a Memorandum of Understanding (MOU) signed between the NZ Government and agricultural industry in 2003 states that the Crown will bear the costs of the agricultural sector's non-carbon dioxide emissions on the basis that "there are currently no proven, practical and cost effective technologies to reduce agricultural emissions"(MOU 2004).

Since 1990 NZ's agricultural sector has increased nitrogen fertiliser use per hectare, per stock unit and per unit of output (Woodford 2006). However fifty percent of N fertiliser applied to farmland can be lost to the environment as nitrate (NO_3-) or nitrous oxide (N_2O) (MA 2005), with the primary source of nitrogen loss from grazed pasture soils being animal urine (Di et. al. 2007). Nitrous oxide is one of six greenhouse gases (GHG) targeted for reduction by the Kyoto protocol and has a global warming potential (GWP) 298 times that of carbon dioxide (Forster et al. 2007). In December 2002 New Zealand ratified the Kyoto Protocol as part of the global commitment to reduce GHG emissions. NZ committed to reducing its emissions to 1990 levels, however by 2005 NZ's GHG emissions were 25% higher than in 1990 (MfE 2007). Between 1990 and 2005 NZ's nitrous oxide emissions increased by 27%, with 96% of NZ's nitrous oxide emissions attributable to the agricultural sector (MfE 2007).

Figure 1. New Zealand's total greenhouse gas emissions by sector: 2006 (MfE, 2008). New Zealand's agriculture sector is the country's largest emitter of greenhouse gases.



Nitrogen (N) constitutes 78% of air as nitrogen gas (N_2), and as a component of proteins and amino acids is essential to life (Vitousek et al. 1997). To be used by plants nitrogen gas must be "fixed" and this occurs naturally or through human activities. In nature nitrogen is often the limiting nutrient for plant growth (Vitousek et al. 1997), but globally the application of fertiliser to land by humans is twice that fixed by nature (MA 2005). This has lead to dire warnings in international reviews of the environment. For example the Global Environmental Outlook 2000 (GEO-2000) warned "*we are fertilizing the Earth on a global scale and in a largely uncontrolled experiment*" (UNEP GEO 1999), and the Millennium Ecosystem Assessment (MA) released in 2005 noted that excessive nutrient loading was one of the "*most important direct drivers of ecosystem change in terrestrial, freshwater, and marine ecosystems*". The MA also found that the flux of reactive nitrogen in some marine regions has increased up to fifteen fold as a result of human activities (MA 2005). Globally, excess reactive nitrogen is a serious threat to human and environmental health, as the ingestion of nitrate causes the oxidisation of hemoglobin, rendering it unable to transport oxygen to body tissue (NPI 2005). This is a particular threat to infants and the United States Environmental Protection Agency (EPA) sets a Maximum Contaminant Level (MCL) of 10ppm in drinking water (EPA 2006).

Efforts to curb the externalities of N fertiliser use include the establishment of Nitrate Vulnerable Zones (NVZ), such as within the European Union Nitrate Directive and the United Kingdom's Catchment Sensitive Farming Programme. With nitrous oxide included in the Kyoto Protocol, added financial pressure to reduce agricultural nitrogen loss can develop where the 'polluter pays principle' is applied. The Kyoto Protocol establishes a 'cap and trade' system under the United Nations Framework Convention on Climate Change (UNFCCC). Under this system developed nations have committed to a collective emissions cap, and countries that cannot meet their individual targets are able to utilise market mechanisms including emissions trading (UNFCCC).

In New Zealand the environmental costs of nutrient loss have, and continue to be, borne beyond the farm (Woodford 2006). The agricultural industry is excluded from the NZ Emissions Trading Scheme (NZ ETS), until after the first commitment period of the Kyoto Protocol (KP1) which runs from 2008 - 2013. Agriculture's exclusion from the NZ ETS is in accordance with the MOU signed between the Government and agricultural industry in 2003 (MOU 2004). However groups such as the Sustainability Council, Greenpeace NZ (Scoop 30/07/08) and the NZ Green Party (Scoop 12/06/08) maintain that the agricultural sector should be brought into the ETS during KP1; that there are now proven, practical and cost effective methods to reduce nitrogen emissions; that the conditions on maintaining the MOU have not been met by the agricultural industry; and that these conditions have been amended without the necessary formal review, invalidating this agreement.

In an opinion piece in the New Zealand Herald Simon Terry from the Sustainability Council asserts that it costs less to purchase emission reductions from the agricultural sector than to buy overseas credits, and that the resulting gain in efficiency would boost farmer profits:

> *A consultant study completed for the Government estimates that 60 per cent of all emissions that could be saved for less than $30/tonne are agricultural. Further, the five techniques it documents for cutting emissions - such as applying nitrification inhibitors - would actually boost farmers' profits today* (New Zealand Herald 23/07/08).

One potential strategy for the reduction of nitrous oxide emissions is the utilisation of high sugar ryegrass cultivars (HSG). HSG are digested more efficiently by ruminants resulting in less nitrogen excreted as waste (Miller et al. 2001). The purpose of this study is to assess the potential to reduce NZ's agricultural nitrous oxide emissions through the utilisation of high sugar grasses, and to investigate whether reducing nitrous oxide emissions through the use of HSGs is a least cost option for GHG abatement.

Background Information

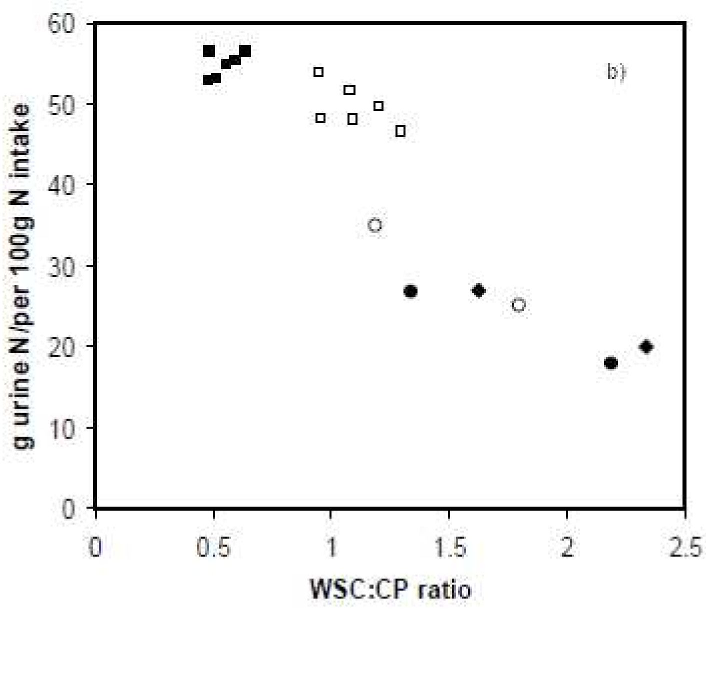
The addition of synthetic nitrogen fertiliser into agricultural systems has been a major component of the 'green revolution' which enabled food production to keep pace with population increase during the latter half of the 20th century (MA 2005). However the beneficial affects of nitrogen addition eventually plateau in a manner similar to the 'law of diminishing returns', i.e. eventually more of each additional unit of fertiliser is lost to the environment and less taken up by crops (MA 2005). Furthermore the harmful environmental threshold of nitrogen addition can be much lower than the point at which nitrogen addition is no longer economically viable (Woodford 2006).

Pastures fertilised with high rates of nitrogen are high in protein (Frame 1991). However the efficiency of ruminants in converting dietary protein into meat, milk or fibre decreases as the dietary protein content increases (Sannes et al. 2002). Rumen microbes utilise energy from the fermentation of soluble carbohydrates to break down structural plant fibres. High fertiliser rates decrease the water soluble carbohydrate (WSC) content of ryegrasses. This is attributed to the increased growth rate of the grass (Hoekstra et al. 2007). Leaf proteins in grass are highly soluble and when the carbon skeletons are used as an energy source the nitrogen component is excreted as waste (Marley et al. 2007, Sannes et al. 2002). Increasing the proportion of readily fermentable carbohydrate in the diet of ruminants increases the digestive utilisation of protein by the animal (Miller et al. 2001).

New Zealand's pastoral system is predominantly based on a mixed pasture of white clover (Trifolium repens) and perennial ryegrass (Lolium perenne) (Di et al. 2007). White clover fixes atmospheric nitrogen, and is one of the highest quality forages available (Rattray 2005). White clover can fix from 100 to 350kg N ha-^{1} on average per year (Rattray 2005). At the current urea fertiliser price of $929 per tonne, this is equivalent to $200 to $700 per hectare annually (urea 46% nitrogen), plus the associated GHG emissions that would have resulted from urea production and transport. Clover has a higher proportion of crude protein (CP) than ryegrass, and clover protein degrades more easily in the rumen (Rattray 2005). The relative utilisation inefficiency of plant nitrogen by grazing animals is a feature of the NZ pastoral system, with reported nitrogen retention values by animals of 16% on a typical dairy farm and 8% on a typical hill country sheep farm (MAF 2003).

High sugar grasses are ryegrass cultivars selectively bred to express substantially higher WSC concentration than standard ryegrass cultivars. The higher WSC content provides more energy to rumen microbes, which can increase the digestive utilisation of nitrogen. Reducing nitrogen excretion by ruminants can be achieved either through increased digestive utilisation of nitrogen, and/or reduced protein content in feed (Yan et al 2006, Yan et al. 2007). Edwards et al. (2007) reviewed a number of trials of HSGs and found that the reported responses of dairy cows formed a continuum, which related to the ratio of WSC to CP, rather than WSC content alone.

Figure 2. Synthesis of N utilisation efficiency for urine in dairy cows from a range of studies. The combined data shows a relationship between N utilisation efficiency, and the WSC to CP ratio of the forage component of the diet (Edwards et al. 2007).



Aim and Objectives

The aim of this research is to answer the following question: Is converting pasture to High Sugar Grass (HSG) cultivars a cost effective strategy to reduce New Zealand's agricultural nitrous oxide (N_2O) emissions?

Answering this question necessitated breaking the task into objectives as follows:

1: **Effect of HSGs on nitrogen loss by ruminants:** What effect do high sugar grasses have on nitrogen excreted in urine by ruminants compared with conventional ryegrass cultivars?

2: HSG field performance, management and production: How do HSGs perform in the field? Are there specific management considerations? And what effect does the ingestion of HSGs by ruminants have on the production of meat or milk?

3: Greenhouse Gas accounting: How much can HSGs reduce nitrous oxide emissions by? Can converting pasture to HSG cultivars be achieved for less than $30 per tonne of carbon dioxide equivalent emissions saved? And what is a likely timeframe for re-sowing pasture with HSG cultivars?

Methods

To achieve objectives one and two information was gathered from peer reviewed journal articles. Search engines used to access peer reviewed literature were Web of Science, Science Direct, Scopus and Proquest. **Search keywords:** objective 1; lolium, ryegrass, nitrogen, utilization, efficiency, water soluble carbohydrate, high, sugar, urine, excretion. Objective 2; lolium, high, sugar, water soluble carbohydrate, ryegrass, yield, nutrition, cultivars, production. Answering objective 3 involved reviewing literature produced for or by the Intergovernmental Panel on Climate Change (IPCC), UNFCCC, NZ Ministry for the Environment (MfE) and Ministry of Agriculture and Forestry (MAF) and interviewing a leading NZ farm manager.

Results

Effect of HSGs on Nitrogen loss by Ruminants

Miller et al. (2001) measured 26% lower urine nitrogen (N) excreted from dairy cows in late lactation fed HSG versus cows fed a control grass. Cows fed the HSG diet yielded significantly more milk on average daily (18%), and the milk produced by cows on the HS diet had significantly higher protein content.

Grass Characteristics: The HSG cultivar for this experiment was Ba11353, an experimental variety bred by the Institute of Grasslands Research (IGER) in Wales, the control variety was AberElan. Two applications of fertiliser 62.5kgN ha^{-1} each were applied two months apart, with the final application 2 months prior to the experiment commencing. Both grasses were harvested in the afternoon, with an average water soluble carbohydrate (WSC) content of 165g kg^{-1} and 126g kg$^{-1,}$ and WSC to crude protein (CP) ratios of 1.8:1 and 1.2:1 for the HSG and control respectively.

Diet characteristics: The cows were also given 4kg of concentrate per day with a 1:3.4 ratio of WSC to CP. Average total nitrogen intake for cows on HS diet was 290g day^{-1}; this was not statistically different to that of cows on the control diet at 280g day^{-1}.

Moorby et al. (2006) found that dairy cows in early lactation given the HSG treatment consumed 17% more dry matter, which resulted in a significantly higher intake of dietary nitrogen. Milk protein output was 12.5% higher, with no significant difference in milk yield. There was a 14% decrease in urinary N excretion for the HSG treatment, despite N excretion being low in both treatments.

Grass characteristics: The HSG cultivar for this experiment was Ba11353, and the control AberElan. An application of fertiliser providing 62.5kgN ha^{-1} was applied two months prior to the experiment commencing. The HSG cultivar was harvested in the afternoon, and the control harvested in the morning, this utilised natural diurnal WSC differences to accentuate the WSC difference between treatments. The average WSC content was 165g kg^{-1} (HSG) and 126g kg^{-1} (control) CP difference was not significant between treatments. The WSC to CP ratio of the HSG treatment was 2.3:1 and in the control 1.6:1

Diet Characteristics: Cows were also given 4kg of concentrate per day with a 1:2.1 ratio of WSC to CP. Average total nitrogen intake for cows on the HSG diet was significantly higher at 376g day^{-1}; compared to cows on the control diet at 320g day^{-1}.

HSG Field Performance, Management and Production

Fertiliser considerations: In field trials of HSGs conducted in Ireland, **Hoekstra and Schulte (2008)** showed that lower application rates of N fertiliser and longer rotation lengths were important tools in manipulating N and WSC content of pasture during early and mid season. The effect of N fertiliser is reduced towards the end of the season, since much of the pasture has been affected by dung and urine (High N inputs). They also found that the relative difference in WSC content between high and low sugar cultivars was greatest late in the season. They suggest that since this is when the risk of environmental N loss is greatest, due to high N content in grass and greater risk of leaching (Hoekstra et al. 2007) it is also when the N efficiency effects of grazing HSGs are most needed.

Australian Trials: Smith et al. (1998) compared the performance of HSGs and regular cultivars in three contrasting Australian dairy environments at Kyabram, Victoria, and Gatton, Queensland, and under natural rainfall at Condah, Victoria, during 1995–97. They found that the HSG cultivars (cv. Aurora and breeding line Ba 11351 of UK origin) yielded poorly and were more susceptible to crown rust which further reduced yield. However the HSG cultivars had consistently higher WSC concentrations in all environments throughout the growing season. For all cultivars WSC content was lowest at Gatton in Queensland, which rarely reached 150 g/kg, contrasting with Condah in Victoria where all cultivars maintained WSC concentrations near or above 150 g/kg. Smith et al. (1998) also note that crown rust resistance and yield can be improved through hybridising with local cultivars.

Francis et al. (2006) conducted a field trail over nine days during May in Victoria comparing the preference of cows for the cultivar AberDawn (which is no longer considered a high WSC cultivar (Edwards et. al. 2007)) with a control (AberElan), and with white clover. The cows spent more time grazing, and consumed more of the control, exhibiting a greater partial preference for the control over AberDawn. The WSC to CP ratio was better in the control at 1.5:1 than in the WSC cultivar at 1.3:1. The WSC content of the control was also higher at 187 g/kg DM compared with 179g/kg DM for AberDawn. Both ryegrass cultivars were moderately infected with crown rust (*Puccinia coronata Corda f. sp. lolii Brown*) during the preceding February and March and were fertilised with nitrogen to limit the impact of this infection (fertiliser application details not given).

Effect of HSG on animal production in field trials: Lee et.al (2001) compared the live-weight gain of the suckling lambs of mothers grazing BA11353 (an early IGER HSG cultivar) to that of a control in Wales. Herbage yield was 5.8% greater in the HSG plots, and weight gain 23% higher on HSG plots compared to control plots. The WSC concentration of BA11353 averaged 116 g/kg DM ha^{-1} with a WSC to CP ratio of 1:1.5, whereas the WSC content of the control averaged 82.6 g/kg DM ha^{-1} with the WSC to CP ratio at 1:2.1. 250 kg ha^{-1} N was applied to all plots around one month prior to the experiment.

Marley et al. (2007) compared live-weight gain of finishing lambs grazing the HSG cultivar AberDart versus a control, both under continuous and rotational grazing in Wales. In general rotationally grazed lambs performed better, with more efficient N utilisation, and the lambs rotationally grazing AberDart also had significantly higher final live-weight than other lambs, despite no difference in herbage intake. In this experiment, the WSC content of AberDart averaged 114 g/kg DM ha^{-1} with a WSC to CP ratio of 1:1.8, whereas the WSC content of the control averaged 100 g/kg DM ha^{-1} with a WSC to CP ratio of 1:2.1. N fertiliser treatment involved 4 to 5 applications of a NPK (28:8:11) compound fertiliser each providing 50 kg ha^{-1} of N.

Greenhouse Gas Accounting

Inadequate information was found in the literature from which to quantify the reduction in N_2O emissions as a result of adopting HSG. However, for the purposes of this study some basic assumptions can be made to produce an estimate. The IPCC Guidelines for National Greenhouse Gas Inventories for N_2O emitted from excrement deposited on Pasture Range and Paddock (PRP) give a value of 1% of nitrogen deposited to PRP by sheep, and 2% by cattle. Sheep have a lower value since they distribute urine more frequently and evenly, and cause less soil compaction (IPCC 2006).

A higher ratio of WSC in the diet has been shown to reduce nitrogen in urine by 25% (Miller et al. 2001). In NZ animals usually graze a mixture of HSG with white clover, in warmer conditions than in Wales, and there is a current trend toward higher rates of N fertiliser application. Therefore NZ pasture is likely to be higher in protein, resulting in a lesser reduction of urine N than that obtained by Miller et.al. (2001) (see Analysis and Discussion section). To produce an estimated reduction of N_2O as a result of converting pasture to HSG cultivars in NZ, an assumption of a 15% reduction in nitrogen from animal excrement will be used.

A further assumption is that in general only more intensively grazed pasture on flat land will be re-sown. Therefore for the purposes of this estimate it is simplest to focus on dairy pasture. In June 2007 there were an estimated 5.2 million dairy cattle (NZ Meat and Wool Economic Service Stats), which excreted 117 kg N/head/yr to PRP (NZ GHG Inventory 1990 – 2004), onto the 1 742 242 ha of NZ's Grassland used for Dairy Cattle Farming (Statistics NZ 2007).

Table 1. Calculating the value of N_2O reduction from High Sugar Grasses Estimated dollar savings based on HSGs reducing urine N by 15%.

Calculation	Result
5 200 000 dairy cattle x 117 kg N/head/yr	608 400 000 kg N deposited to PRP each year
608 400 000 kg N x 15% reduction through utilisation of HSG	A 15% reduction saves 91 260 000 kg N to PRP each year
91 260 000 kg N x 2% lost to the atmosphere as N_2O	1 825 200 kg N lost to the atmosphere as N_2O
1 825 200 kg N / 28 (Mw of N_2) = 65'186 moles of N_2, then add oxygen 65'186 moles x 16 (Mw of O)	2 868 171 kg of N_2O
The global warming potential (GWP) of N_2O is 298 times greater than CO_2; 2 868 171 x 298	854 715 tonnes of carbon dioxide equivalent.
854 715 tonnes of carbon dioxide at $30 per tonne of CO_2	**$25.6 million per year**

Sowing costs and HSG pasture conversion time: Perennial ryegrass pasture typically lasts around 5-6 years, with most NZ dairy farms re-sowing around 10% of pasture per year (McGill 2008). Therefore if utilizing the present pasture renewal routine, the cost of converting pasture to HSG cultivars would be the difference in seed price between conventional ryegrass cultivars, and the new HSG cultivars. Conventional grass seed is priced around $8 per kg ($9 incl.gst). A quote of $9.80 kg incl.gst was obtained for HSG cultivar AberDart (Allied Farmers 15/10/08, Ph: 0800 255 3276).

Table 2. General costs for re-sowing pasture (McGill 2008). Estimated cost to renew 10% of pasture per year.

Component	Cost ($ NZD)
Spray (chemical and application)	$80/ha
Direct Drilling[1]	$200/ha (contractor rates) (full cultivation - $350/ha)
Slug bait if direct drilling 5kg at $12 kg	$60/ha
Seed 20kg grass at $8 kg	$160/ha
5kg Clover[2] at $12 kg	$60/ha
Fertiliser - 100kg DAP at $1500 tonne	$150/ha (18 kg ha^{-1} N)
Sub total	**$710/ha** (direct drilling)
$710 x 1 742 242 ha of NZ Grassland used for dairy farming	$1 236 991 820 (to re-sow all dairy pasture)
$1 236 991 820 over 10 years	**$124 million per year**

Table 3. Cost to re-sow all dairy pasture with HSG cultivars Estimated cost of converting pasture to HSG cultivars based on the difference in price between HSG and conventional ryegrass cultivars.

Component	Cost ($ NZD)
Seed 20kg AberDart at $9.80 kg	**$16/ha**(difference)
$16 x 1 742 242 ha of NZ Grassland used for dairy farming.	$27 875 872
$27 875 872 over 10 years	**$2.8 million per year**

[1] The release of N through the mineralisation of soil organic matter as a result of land management is included as a 'source' (of GHG) in the 2006 IPCC inventory guidelines. Therefore sowing by direct drilling (a 'no-till' cultivation technique that retains soil structure, nutrients, carbon and moisture) rather than full cultivation would further reduce NZ's emissions liability.

[2] The 2006 IPCC inventory guidelines exclude biological nitrogen fixation from legume crops/forages as a direct source of N_2O emissions. As a nutritious feed that helps minimise the addition of synthetic nitrogen clover seed is included when sowing.

Analysis and Discussion

Utilisation efficiency of nitrogen: Miller et al. (2001) and Moorby et al. (2006) were the only studies found using the specified methodology that specifically measured nitrogen excreted as a response to ingestion of HSGs. Both of these studies involved indoor stall-fed cows that were also given supplementary feed, and confirm that consuming HSG can reduce the amount of nitrogen excreted in urine and increased the amount of protein in milk. In both these experiments, the WSC to CP ratios of the controls were better than the HSG cultivars in many other HSG trials (1.2:1 and 1.6:1 respectively). For example the WSC to CP ratio in Lee et al. (2001) was 1:1.5, and 1:2.1 in the HSG and control respectively. Despite the WSC content of the control cultivars being relatively high, there were still marked differences between treatments in both these experiments. In particular, despite the cows in the HSG treatment in Moorby et al. ingesting more CP than cows on the control diet, N excretion was still reduced. This observation supports the finding of Edwards et al. (2007) that N utilization efficiency is related to the ratio of WSC to CP.

HSG performance, management and production: The results of the Australian trial by Smith et al. (1998) indicate that WSC in general is a function of temperature, and that HSG cultivars can consistently maintain higher WSC concentrations than conventional cultivars. Interpreting the results of Francis et al. (2006), shows that stock preferentially select the cultivar with better WSC to CP ratio. In the trials of Lee et al. (2001), and Marley et al. (2007), the comparative performance of lambs on HSG treatments was considerably better than their control counterparts. Marley et al. (2007) also found that rotational grazing enables the utilisation of further gains in production efficiency.

The relationship between improved WSC to CP ratio and increased production and reduced nitrogen loss is strongly supported in the literature reviewed (i.e. presented in the results section). Also supported across this literature is that the rate of fertiliser, as shown by Hoekstra and Schulte (2008) is important in determining N/CP and WSC content. There is a notable contrast between the amount of N fertiliser used, and the WSC concentration and WSC to CP ratios achieved in the experiments of Miller et al. (2001) and Moorby et al. (2006) (low N application), versus the trials of Lee et.al (2001) and Marley et al. (2007) (high N application). The WSC component of the grass was greater than the CP component in Miller and Moorby's experiments (low N), but the CP component greater than WSC in Lee and Marley's trials (high N). As previously mentioned the differences between these sets of studies were so great that the controls used by Miller and Moorby, had higher WSC and better WSC to CP ratios than the HSG cultivars used in the trials by Lee and Marley. Yet in both sets of studies, since the WSC content and WSC to CP ratios were worse in the respective controls relative to the HSG treatments, significant benefits were evident in the HSG treatments. The evidence from the literature also suggests that higher rates of fertiliser application increase the proportion of dietary nitrogen lost to the environment in general, and therefore rates of fertiliser application need to be taken into account in calculating N_2O emissions from urine.

No studies undertaken in New Zealand were found in the literature found using the methodology stated for this study. However AgResearch, a NZ Crown Research Institute (CRI), was commissioned by Germinal Holdings to trial the performance of IGER cultivars AberDart, AberAvon and AberMagic under NZ conditions. Two trials were conducted over three years at Palmerston North (North Island) and Gore (South Island) between 2000 and 2006 (Edwards et al. 2007). Unfortunately this trial did not result in a peer reviewed journal article. An agreed joint statement was issued by AgResearch and Germinal seeds on the basis of "commercial sensitivities" (Edwards et al. 2007). In the joint statement both parties agreed that the IGER HSG cultivars grew well, with an overall similar or better (up to 29%) yield than regular cultivars, with 7 to 13% higher WSC content and AberMagic was significantly less affected by an incident of crown rust than all other cultivars. Data on fertiliser application, actual WSC and CP concentrations were not provided (AgResearch and Germinal Seeds NZ 2007).

AgResearch is currently working on breeding an AberDart equivalent with a commercial company, and it is expected to take another 4-5 years before a NZ developed HSG cultivar is available for commercial release (Country-Wide 2007). However Germinal Seeds are releasing advanced varieties such as crown rust resistant AberMagic (NZ Dairy Exporter 2007). It seems there is an emerging commercial competition in HSG cultivars, but unfortunately protecting "commercial sensitivities" may not be assisting the transition of NZ farmers to HSG cultivars. The ability of AgResearch to provide independent information in this situation is also questionable. This lack of transparency coupled with a paper by AgResearch scientists titled "Some High Sugar Grasses don't like it hot" delivered to a NZ Grasslands Association conference in 2004, may have created confusion for farmers (Country-Wide 2007).

GHG reduction accounting: The cost of utilising HSG to reduce N_2O emissions is likely to be much less than purchasing international emission allowances. The estimate produced for this study is nearly 10 times less than the cost of purchasing carbon equivalent units at $30 per tonne. However, as is characteristic with ecological studies, there are many variables, and non-linear responses to change. Modeling of pasture WSC and CP in response to N fertilizer application rate, and nitrogen excretion in response to changing WSC to CP ratios, along with modeling of the WSC to CP ratio in response to climate factors would be required to quantify the reduction in emissions as a result of converting pasture to HSG cultivars.

Under present pasture management practice, 50 percent of a farm is re-sown over a five year period. However without access to robust and independent information on performance benefits of HSG, or to enable inclusion in an inventory, then re-sowing with HSG will be ad-hoc. Investment in research, inventory development, seed production capacity, and remitting the price difference for conversion to HSG are potential incentives and could reduce the conversion time. If 15% of pasture was re-sown each year, total conversion to HSG cultivars would take 6 years. While there will be other factors influencing a farmers choice of ryegrass cultivar to sow, HSGs could be effectively utilised in conjunction with efficient synthetic N fertiliser use as part of a "best practice" effort to reduce farm GHG emissions.

The NZ Government expects the Agriculture sector to start taking steps towards reducing emissions before inclusion in the NZ ETS in 2013. The Government will also require the sector to monitor and report its emissions from 2012 (MAF website accessed 16/10). Therefore the imperative to undertake research and development into mitigation avenues developing an inventory to incorporate these avenues is currently established. One prospect to reward early conversion to HSG cultivars for prior to 2013 may be utilising the voluntary carbon market. For example a farm or business producing or servicing a high value niche market, may seek added distinction from its competitors though carbon neutral certification. In the voluntary carbon market, a farm that has abated its cost effective GHG emissions, i.e. on-farm reductions below the price of off-farm abatement, could offset its remaining emissions by purchasing reductions elsewhere. An example of this is the New Zealand Wine Company (NZWC) which produces the Grove Mill and Sanctuary wine labels, and markets itself as the world's first "carbon zero" winery. Grove Mill offsets its emissions through the CarboNZero programme by Landcare Research. (http://www.grovemill.co.nz/page/home accessed 6/10). Other participants achieving certification through the CarboNZero programme include TradeMe, NZ's largest e-commerce company, Meridian Energy, TrustPower, and Toyota NZ. Individuals also participate in the voluntary market including golfer Michael Campbell, cricketer Brendon McCullum, olympic rowers Caroline and Georgina Evers-Swindell, and rugby player Conrad Smith (http://www.carbonzero.co.nz accessed 06/10).

To qualify for carbon market funding a project must demonstrate additionally, i.e. emissions reduction would not have occurred without carbon market funding (WBCSD and WRI 2005, Ward and Weaver 2008). Also GHG reductions must be quantified relative to a baseline scenario (WBCSD and WRI 2005). HSG could be viewed in a similar fashion to energy efficiency projects, i.e. there are co-benefits such as health, comfort and financial savings through retrofitting insulation into houses, but in a baseline scenario this occurs in a gradual and ad-hoc manner. Carbon market funding can be demonstrated to reduce additional emissions above the baseline scenario, which also enables the co-benefits to be realised sooner.

It is apparent that substantial co-benefits may be present to the extent that HSG will be utilised for increased milk or meat production, However there are key gaps in the literature that need to be addressed to enable HSG to be utilised with greater certainty, either for increased production, or for a reduction in environmental nitrogen loss. There is also a potential to utilise modelling of fertiliser application rate and WSC to CP ratios to enable more efficient nitrogen fertiliser use.

Conclusion and Recommendations

HSG consistently achieve better WSC to CP ratios that conventional ryegrass cultivars grown under the same conditions. In all studies accessed, the treatments with the better WSC to CP ratios had improved production, palatability, or reduced nitrogen excretion than their respective controls. Also, within current pasture renewal practice, conversion to HSG cultivars is a minimal cost. Therefore there is sufficient evidence to support the claim that HSG are a practical and cost effective method for reducing nitrous oxide emissions from agriculture, with the added potential of increasing farm profits. However more information is required for any reduction to be included in a national GHG inventory, or to enable quantification against a baseline scenario. It is not currently possible to include N_2O mitigation from High Sugar Grasses in New Zealand's GHG inventory; therefore it is also not currently possible for High Sugar Grasses to assist in complying with NZ's Kyoto Protocol obligations during KP1.

It is unfortunate that the New Zealand based trials were not conducted in an independent and transparent manner, since despite trials occurring, New Zealand farmers have had insufficient information on which to make long term pasture management decisions with regard to HSG. UK farmers have access to a national seed list, and National Listing is a legal requirement (under EU directives) for certification and marketing of the main agricultural plant species. National trials are conducted over a minimum of 2 years, into the distinctness and quality characteristics of the new cultivar and its value for cultivation and use (DEFRA 2005). The NZ agricultural industry may also benefit from a similar system.

The primary challenge in addressing climate change is mobilising a decisive and effective response. With potentially 60% of all New Zealand's emissions reductions that could be achieved for less than $30 per tonne in the agricultural sector, there is considerable opportunity for farmers to participate in the voluntary carbon market prior to 2013. Utilising carbon market funding can facilitate the establishment of GHG reduction projects and enable reductions sooner. To enable farmers to access the voluntary carbon market, or to quantify a reduction in emissions from converting pasture to HSG cultivars some specific research is required. Nitrogen excretion at differing ratios of WSC to CP in pastures needs to be modelled, and variation in WSC to CP ratio in response to climate factors. Modelling the variation in WSC to CP ratio in ryegrass as a response to differing rates of N fertiliser may also be required for conventional ryegrass, given the trend towards increasing nitrogen fertiliser use in New Zealand. The WSC to CP ratio of pasture plays a large role in nitrogen utilisation and excretion in ruminants and animal excreta is the largest source of N_2O emissions in NZ (Di et al. 2007, de Klein and Ledgard 2005). Therefore the relationship between N fertilizer and pasture WSC to CP ratio needs be taken into account in New Zealand's GHG emissions inventory.

References

Agresearch and Germinal Seeds NZ (2007), Joint media statement 16 February 2007 http://www.germinalnz.co.nz/scientific-information/grasses-perform-to-expectation.aspx accessed 29/09/08

Chapman, D.F., Parsons, A.J. & Schwinning, S. 1996. Management of clover in grazed pastures: expectations, limitations and opportunities. In: White Clover: New Zealand's Competitive Edge. Symposium of the New Zealand Grassland Association, Lincoln, N.Z., pp. 55-64.

Country-Wide Publications 2007. Sugar ryegrass spat leaves sour taste 01-01-2007 Terry Brosnahan http://www.country-wide.co.nz/article/6420.html accessed 15/09/08

DEFRA, United Kingdom Department for Environment Food and Rural Affairs. Guide to National Listing of Varieties of Agricultural and Vegetable Crops in the UK http://www.defra.gov.uk/planth/pvs/guides/niguide-20050317.pdf

Di, H.J.; Cameron, K.C. 2002: The use of a nitrification inhibitor, dicyandiamide (DCD), to decrease nitrate leaching and nitrous oxide emissions in a simulated grazed and irrigated grassland. Soil Use and Management 18: 395-403

Di, H.J., Cameron, K.C., and Sherlock, R.R., 2007. Comparison of the effectiveness of a nitrification inhibitor, dicyandiamide, in reducing nitrous oxide emissions in four different soils under different climatic and management conditions. Soil Use and Management, March 2007, 23, 1-9

de Klein C.A.M, and Ledgard, S.F., 2005. Nitrous oxide emissions from New Zealand agriculture – key sources and mitigation strategies. Nutrient Cycling in Agroecosystems (2005) 72: 77–85

Edwards G.R., Parsons A.J., Rasmussen, S. 2007. High sugar ryegrasses for dairy systems. In: Meeting the challenges for pasture-based dairying. (Chapman D.F., Clark, D.A., MacMillan K.L., Nation D.P. eds). University of Melbourne, National Dairy Alliance pp 307-334.

EPA., United States of America Environmental Protection Agency http://www.epa.gov/safewater/dwh/c-ioc/nitrates.html last updated November 2006, accessed 16/08/08

Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 2007: Changes in Atmospheric Constituents and in Radiative Forcing. *In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor M., and Miller H.L., (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Frame, J. 1991. Herbage production and quality of a range of secondary grass species at five rates of fertilizer nitrogen application. Grass Forage Science. 46:139.

Francis, S.A., Chapman, D.F., Doyle, P. T., and Leury, B. J., 2006. Dietary preferences of cows offered choices between white clover and'high sugar' and 'typical' perennial ryegrass cultivars. Australian Journal of Experimental Agriculture, 46, 1579–1587

Hoekstra N.J., and Schulte, R.P.O., 2008. Modelling the concentrations of nitrogen and water soluble carbohydrates in grass herbage ingested by cattle under strip-grazing management. Grass and Forage Science, 63, 22–37

Hoekstra N.J., Struik P.C., Schulte R.P.O. and Lantinga E.A. 2007. Chemical composition of lamina and sheath of Lolium perenne as affected by herbage management. NJAS, Wageningen Journal of Life Sciences, 55, 55–73.

IPCC., Intergovernmental Panel on Climate Change (online) http://www.grida.no/Climate/ipcc/emission/168.htm accessed 16/08/08

IPCC Guidelines for National Greenhouse Gas Inventories 2006. Volume 4: Agriculture, Forestry and Other Land Use, Chapter 11 N_2O Emissions from Managed Soils, and CO2 emissions from Lime and Urea application. Authors: Cecile De Klein (New Zealand), Rafael S.A. Novoa (Chile), Stephen Ogle (USA), Keith A. Smith (UK), Philippe Rochette (Canada), and Thomas C. Wirth (USA) Brian G. McConkey (Canada), Arvin Mosier (USA), and Kristin Rypdal (Norway)

Kelliher, F.M. and Clark, H., 2004. Disaggregation and uncertainty in nitrous oxide emissions from New Zealand's agricultural soils: 1990 and 2001. Report to the Ministry of Agriculture and Forestry.

Lee, M.R.F., Jones, E.L., Moorby, J.M., Humphreys, M.O., Theodorou, M.K. MacRae J.C., & Scollan, N.D., 2001. Production responses from lambs grazing on Lolium perenne selected for elevated water-soluble carbohydrate concentration. Animal Research 50: 441–449.

MA, Millenium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: synthesis (online) http://www.millenniumassessment.org/en/Index.aspx accessed 16/08/08

MAF, New Zealand Ministry of Agriculture and Forestry, 2003, Abatement of Agricultural Non-Carbon Dioxide Greenhouse Gas Emissions http://www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/climate/abatement-of-agricultural-greenhouse-gas-emissions/httoc.htm accessed 30/09/2008

MAF website http://www.maf.govt.nz/climatechange/agriculture/ accessed 16/10

Marley, C. L., Fraser, M. D., Fisher, W. J., Forbes, A. B., Jones, R., Moorby, J. M., MacRae, J. C., Theodorou, M. K., 2007. Effects of continuous or rotational grazing of two perennial ryegrass varieties on the chemical composition of the herbage and the performance of finishing lambs. Grass and Forage Science 62(3): 255-264

McGill, P., 2008. Manager - Mayfield Kingsdon Partnership, 2008 PPCS Wairarapa Farm Business of the Year. Personal communications, email 23/09/08.

MfE, New Zealand Ministry for the Environment, 2008. New Zealand's Greenhouse Gas Inventory 1990 – 2006: An Overview (online version) http://www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-overview-apr08/html/figure-5.html accessed 26/09/08.

MfE., New Zealand Ministry for the Environment, 2007. New Zealand's Greenhouse Gas Inventory 1990 – 2005: An Overview (online version) http://www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-overview-jul07/html/page1.html accessed 16/08/2008

Miller, L. A., Moorby, J. M., Davies, D. R., Humphreys, M. O., Scollan, N. D., MacRae, J. C., Theodorou, M. K., 2001. Increased concentration of water-soluble carbohydrate in perennial ryegrass (Lolium perenne L.): milk production from late-lactation dairy cows. Grass and Forage Science 56(4): 383-394.

Moorby, J. M., Evans, R. T., Scollan, N. D., MacRae J. C. and Theodorou, M. K., 2006. Increased concentration of water-soluble carbohydrate in perennial ryegrass (Lolium perenne L.). Evaluation in dairy cows in early lactation. Grass and Forage Science 61(1): 52-59.

Mulet-Marquis, S., and Fairweather, J.S., 2008 New Zealand Farm Structure Change and Intensification, Research Report No. 301 Agribusiness and Economics Research Unit, Lincoln University New Zealand, ISSN 1170-7682 ISBN 978 -0-909042-89-9

NPI., Australian National Pollution Inventory http://www.npi.gov.au/database/substance-info/profiles/68.html last updated May 2005, accessed 16/08/08

New Zealand Dairy Exporter, 2007. All sweetness in high sugar grass. By Steve Searle http://www.archivesearch.co.nz/?webid=DXP&articleid=24895 accessed 29/09/08

New Zealand's Greenhouse Gas Inventory 1990 – 2004 The National Inventory Report and Common Reporting Format Annex 8.4 Worksheets for the agriculture sector

NZ Meat and Wool Economic Service Statistics http://www2.akl.obm.co.nz/meatnz/Livestock.htm?SECID=528580x6405962030 accessed 13/10/08

Rattray 2005 Clover Management, Research, Development & Extension in the New Zealand Pastoral Industries. A Review of: R&D Literature and R&D Opportunities Extension Initiatives and Extension Opportunities. A Report commissioned by the Sustainable Farming Fund. ISBN 0-478-29827-7

R. A. Sannes, M. A. Messman, and D. B. Vagnoni, 2002. Form of Rumen-Degradable Carbohydrate and Nitrogen on Microbial Protein Synthesis and Protein Efficiency of Dairy Cows. Journal of Dairy Science 85:900–908

Scoop 12/06/08 Backroom deal guts agricultural targets Press Release: Green Party http://www.scoop.co.nz/stories/PO0807/S00374.htm accessed 16/08/08

Scoop 21/07/08 25% of New Zealand's export earnings from Fonterra Press Release: Fonterra http://www.scoop.co.nz/stories/BU0807/S00346.htm accessed 17/08/08

Scoop 30/07/08 Vested interests alter deal– Minister kept in dark, Press Release: Greenpeace New Zealand http://www.scoop.co.nz/stories/PO0807/S00374.htm accessed 16/08/08

Smith, K.F., Simpson, R.J., Oram, R.N., Lowe, K.F., Kelly, K.B., Evans P.M., & Humphreys, M.O., 1998. Seasonal variation in the herbage yield and nutritive value of perennial ryegrass (Lolium perenne L.) cultivars with high or normal herbage water-soluble carbohydrate concentrations grown in three contrasting Australian dairy environments. Australian Journal of Experimental Agriculture 38: 821–830.

Statistics New Zealand, 2007 Agricultural Production Census Agricultural Areas in Hectares by Farm Type At 30 June 2007. http://www.stats.govt.nz/tables/2007-ag-prod/Land+use+tables.htm accessed 16/10/08

The New Zealand Herald, July 23 2008. Plan to put price on carbon emissions needs to change By Simon Terry

UNEP GEO team, Division of Environmental Information, Assessment and Early Warning (DEIA&EW) United Nations Environment Programme 1999. Global Environmental Outlook 2000 (online) http://www.grida.no/geo2000/ accessed 16/08/08

UNFCC, United Nations Framework Convention on Climate Change, Kyoto Protocol (website) http://unfccc.int/kyoto_protocol/items/2830.php accessed 16/08/08

Ward, M., and Weaver, S., 2008 Leaders Guide International Emissions Trading and Carbon Markets. Murray Ward, Sean Weaver, and The Climate Group.

WBCSD and WRI, 2005. The GHG Protocol for Project Accounting. World Resources Institute and World Business Council for Sustainable Development, November 2005 ISBN 1-56973-598-0

Woodford, K., 2006. The Intensification of Pastoral Agriculture: some trends and implications. Primary Industry Management, Vol 9, No2, June 2006, pp3-4

Vitousek, P.M., Aber, J., Howarth, Gene, R.W., Likens, E., Matson, P.A., Schindler, D.W., Schlesinger, W.H., and Tilman, G.D., 1997. Human Alteration of the Global Nitrogen Cycle: Causes and Consequences. Issues in Ecology, Number 1, Spring 1997.

Yan T., Frost, J.P., Keady, T.W.J., Agnew, R.E., Mayne, C.S., 2007. Prediction of nitrogen excretion in feces and urine of beef cattle offered diets containing grass silage. Journal of Animal Science; Aug 2007; 85, 8; Career and Technical Education pg. 1982

Yan T., J. P. Frost, R. E. Agnew, R. C. Binnie, and C. S. Mayne, 2006. Relationships Among Manure Nitrogen Output and Dietary and Animal Factors in Lactating Dairy Cows. Journal of Dairy Scence; 89:3981–3991