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NITROGEN AND CARBON INTERACTIONS

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Abstract

This paper considers various landuse alternatives for New Zealand, comparing nitrogen use and greenhouse gas production. It discusses physical and chemical intervention, presents an example from a high input dairy farm with maize block, and shows that removing ruminants from the food production equation is not the panacea imagined.

Concerns about water quality and climate change have resulted in regulations and initiatives at local and national level. These tend to focus on one or the other, overlooking the fact that nitrogen (N) and carbon (C) cycles are inextricably linked.

Ruminants have been blamed for impacts on both, and horticulture and cropping have been promoted as being less environmentally damaging. However, nitrogen loss factors from horticulture and cropping have been estimated globally at 6.4 and 2.7 times that of improved pasture. In areas of relative heavy rain (New Zealand) N loss can be exacerbated, whether or not precision irrigation is the norm.

For agricultural greenhouse gases (GHG) a focus on biological emissions (methane and nitrous oxides) means that the long-term impact of carbon dioxide is omitted. Calculations of carbon dioxide equivalents (i.e., carbon dioxide, methane and nitrous oxide) per hectare for different land uses indicates that impact of some horticulture crops is greater than that of dairying (a factor of 1.5); cropping is generally considerably lower (a factor of 0.25).

Further suggestions of replacing dairy cows with drystock have been made. However, when the calculations are based on optimising grass growth and intake per hectare (for equivalence reasons), N loss is greater from drystock than dairying (and food production is decreased).

N loss from dairying can be further reduced by irrigation (overcoming a photosynthesis deficit and allowing ongoing N uptake into plants and then milk) and use of a low N feed supplement (allowing increased conversion of N in grass to milk by matching carbon requirements); both irrigation and supplement will increase methane marginally because of increased feed intake by animals.

Any land-use change requires analysis of many aspects, not just those receiving media coverage.

Background

The Government has established a goal of ‘Carbon neutral by 2050’, and has various working groups tackling the challenge of ‘how’ the goal might be achieved. At the same time there has been an increased focus on improving water quality in lakes and rivers. The Parliamentary Commissioner for the Environment laid a foundation for water quality in 2012, reporting that the four main problems in waterways were sediment, nitrogen, phosphorus and *Escherichia coli* (Parliamentary Commissioner for the Environment, 2012).

Carbon release to the atmosphere, and nitrogen and phosphorus release to the soil (from where movement can occur to waterways or, in the case of nitrogen, atmosphere) are linked: plants (autotrophs) combine them, and animals (heterotrophs) separate them (Soussanna and Lemaire, 2014). When grazing ruminants are the heterotrophs involved, some of the carbon is returned to the atmosphere as methane, which has a greater impact in terms of greenhouse gas warming potential than the carbon dioxide from which it formed. Of additional concern is that the nitrate and phosphorus excreted by the animal is spatially concentrated, leading to losses to the environment if the growing plants are unable to take up all the nutrients immediately.

Greenhouse gases

The Ministry for the Environment (2018) reports that 'the Agriculture and Energy sectors contributed the most to New Zealand's emissions at 49.2 per cent and 39.8 per cent of gross emissions in 2016 respectively. Methane and nitrous oxide, largely from agricultural sources, made up over half of our gross emissions. The remaining emissions consisted mostly of carbon dioxide (43.8 per cent in 2016), largely from the Energy and IPPU sectors' (Fig. 1).

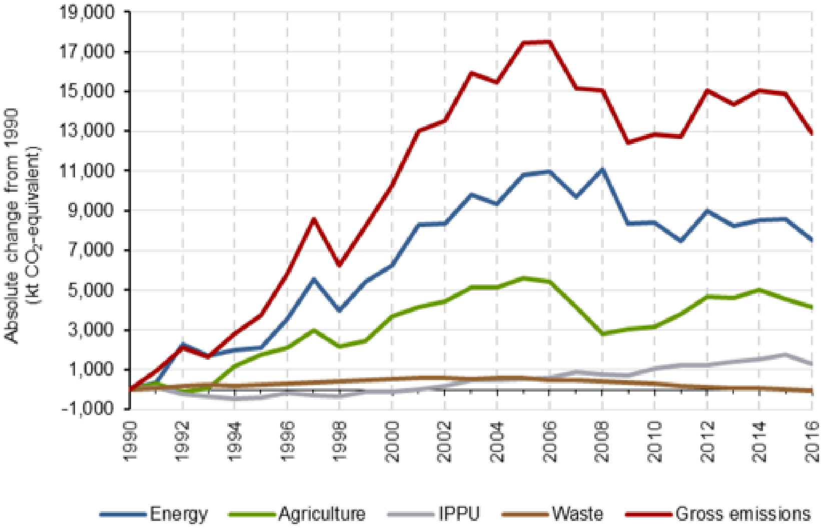

Figure 1. Absolute change in New Zealand's gross emissions (excluding LULUCF) by sector from 1990 to 2016 (Ministry for Environment, 2018)

The focus on agricultural GHG has resulted in repeated suggestions that New Zealand's future lies in horticulture and forestry rather than ruminant animals, particularly dairy cows (e.g., Meduna, quoting Dewes, A., 2018; Salmon, G. Ecologic, pers. comm 2019).

Comparison between milk and meat production

Using the Hurley Pasture Model (Thornley, 1998), a process-based model of the dynamics of carbon (C) and nitrogen (N) cycling between plants, soils and animals in grazed temperate pastures, Parsons *et al*. (2016) clarified how some major components of intensification affect the outcomes (short-term and long-term) of alternative systems for food production (milk or meat) and environmental impact. The model optimises grass growth and consumption and so is optimising all parameters for a given locale (in this case using the soil and meteorological data for Ruakura). At the same intermediate N input (150kgN/ha), food yield (kg N/ha) was twice as much for milk as achieved with meat (Fig. 2a), while with only a small decrease in C sequestration (Fig. 2b) environmental N release was halved (Fig 2c). Methane production was also reduced for milk in comparison with meat (Fig 2d).

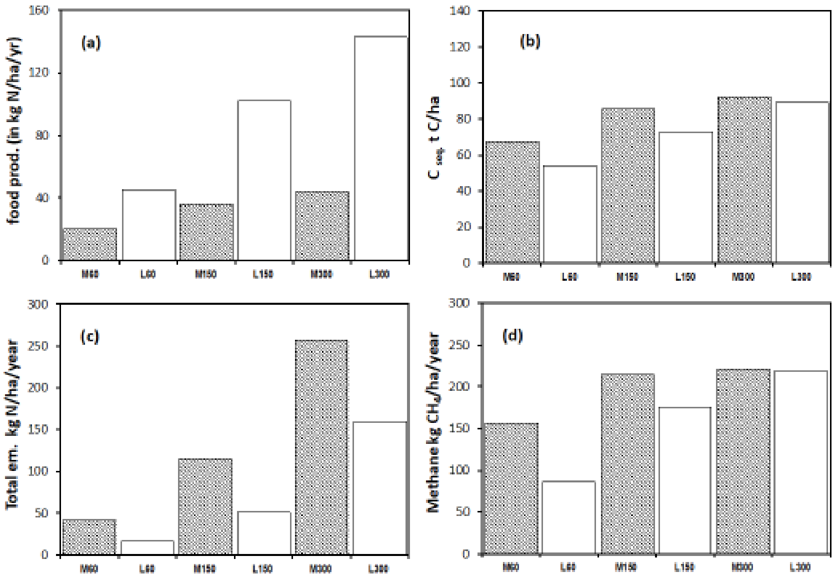

Fig. 2. Partitioning of nutrients into (a) food, (b) carbon sequestration, (c) total N emissions and (d) methane for milk and meat production systems at three nitrogen inputs (Parsons *et al*. 2016)

Further analysis focussed on milk production at a base N input of 150kg N/ha with or without supplement, or with three different soil moisture states (Fig. 3). Together the results show that the sources of sustained changes in N release (e.g., nitrate/ nitrous oxide) were altered inputs (fertilizer/supplements). Much of the increased efficiency in food production reflected 'improved' N partitioning in lactating (cf. dry) animals. Responses to supplements (being a source of C) and to irrigation reinforced the fact that the driving limitation to the grazed ecosystem is C capture per ha. Because increased soil moisture overcomes a drought limitation to growth, carbon capture, nitrogen uptake and food production (Fig. 3a) are increased, and N loss to the environment (Fig. 3c) decreases per hectare. However, because intake is increased, so is methane production for both supplement and irrigation (Fig. 3d)

Authors (Parsons *et al*., 2016) noted that a reversion to dry-stock (or 'de-stocking') would result in increased environmental challenge, unless N inputs were reduced accordingly. However, a move from 150 to 60 kg/ha N would significantly reduce food production (Fig. 2a), and hence income. Note that 150kg/ha N was chosen for further analysis because clover can fix this amount in pasture and research has shown that whether the N comes from clover fixation or from urea makes no difference to the amount leached (Sprosen *et al*., 1997).

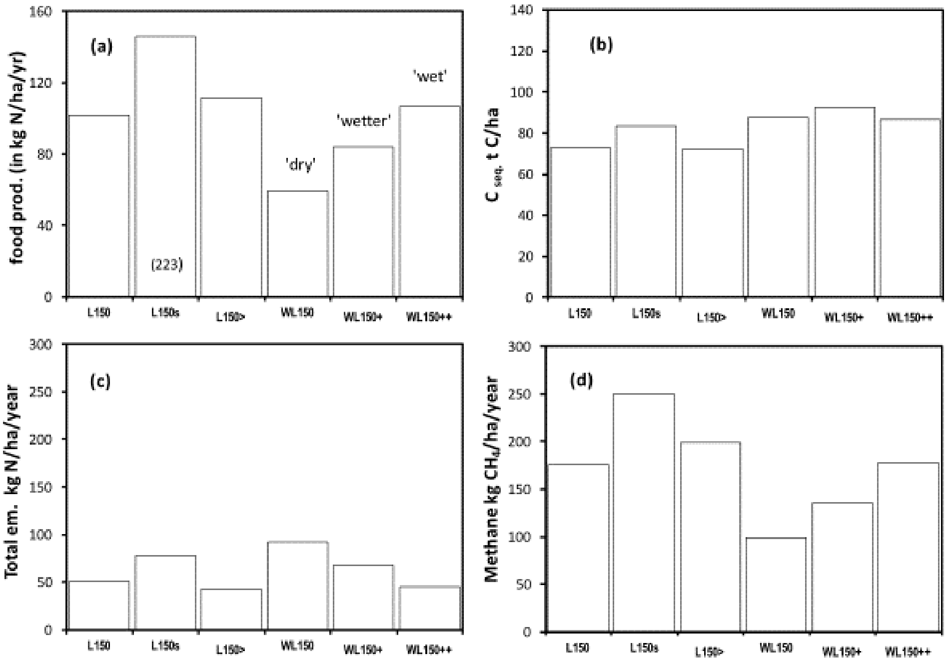

Fig. 3. Partitioning of nutrients into (a) food, (b) carbon sequestration, (c) total N emissions and (d) methane for milk production systems with or without supplement [(s), with no reduction in N fertiliser to account for N in supplement (L150s) and compensation for N in supplement (L150>)] or with three different soil moistures (dry, wet and wetter) based on Winchmore data (Parsons *et al*. 2016)

Potential Nitrogen loss

The suggestion that a move to horticulture and cropping will alleviate nutrient loss to water is not supported by the literature. Farmer and grower expertise make a big difference to efficiencies (Anastasiadis and Kerr, 2013). In the Pukekohe area, the potential for nitrate leaching was calculated as the difference between N input and output (Crush *et al*., 1997). Mean potential for dairying was 157 kg/ha N (range 142-178); early crop potatoes was 429 kg/ha N (range 282-587); main crop potatoes 92 kg/ha N (range 29-181); onions 118 kg/ha N (range 17-230); kiwifruit 166 kg/ha N (range 124-211); squash 238 kg/ha N (range 123-401). The ranges support the notion that good farmers and growers make a difference. So does geographical location (as it affects soil type and climate) as well as the adoption of modern technologies. A review of N losses (N kg/ha/yr) for comparison with kiwifruit (Benge and Clothier, 2016) suggested dairying ranging from 14-81, market gardening 39-73, mixed cropping and arable 1-65, drystock 5-39 and forestry 0-28. Kiwifruit were modelled (using SPASMO) at 3-15 kg/ha/yr N.

Comparison of GHG equivalents

The Biological Emissions Reference Group (BERG) focussed on methane and nitrous oxides with use of models to calculate potential mitigation effects. The BERG report released in December 2018 indicated that ‘emissions from dedicated cropping and horticulture constitute less than 3% of New Zealand’s biological emissions’. The report assessed emissions for the main commodities of kiwifruit, apples, and viticulture for domestic horticulture systems. Wheat and other grains, maize, and ryegrass seed production were the focus for arable land use.

When carbon dioxide equivalents t/ha are calculated, therefore including fuel, chemicals and cultivation (with impacts on soil organic matter), some vegetable and fruit crops appear to be on a par with dairy. It is important to remember that good farmers and growers make a difference as does the area in which the crops are growing. Although the horticulture area of New Zealand is small, the potential is for 2.1 million hectares (Clothier *et al*., 2017); the dairy industry covers 1.755 million hectares. Replacing dairy with horticulture could increase GHG and nitrate impact. The 2.1 million hectares was based on kiwifruit, apples and viticulture, but market size and access affect land use change (Journeaux *et al*., 2017) and many of the higher value market garden crops are associated with considerable GHG production (Fig. 4).

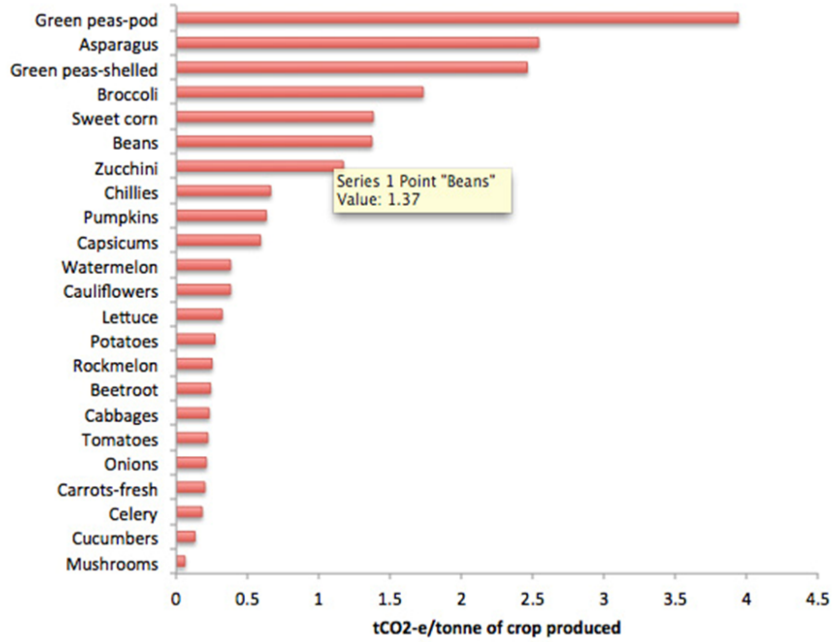

Fig 4. Carbon dioxide equivalents per tonne of vegetable crop produced. (http://www.vegetableclimate.com/climate-credentials/greenhouse-gas-emissions-by-crop/)

Of considerable importance is the fact that a high yielding but lesser GHG producing crop such as potatoes, could at a 50-60t/ha yield be producing almost 20tCO_2-e/ha. A comparison of 25 dairy farms in the Waikato region indicated tCO_2-e/ha of 12 for low input farms and 18 for high input farms (Ledgard *et al*., 2017).
Cereals in New Zealand have been calculated to produce only 2-3 tCO_2-e/ha (Barber et al., 2011), but are not high value crops, nor are they considered to be protein foods like milk and meat.

Synthetic food has also been proposed as an answer to reducing the environmental impacts of food production. However, most require either plants themselves (e.g., wheat, rice, pumpkin, pea isolate) or the energy from plants (i.e., sugar); all are associated with cultivation, chemical application and GHG production. The complications are resulting in an increasing body of research suggesting that 'the climate impacts of cultured meat production will depend on what level of sustainable energy generation can be achieved, as well as the efficiency of future culture processes' (Lynch and Pierrehumbert, 2019).

Genetic technologies are being used in some of the synthetic food systems, including Perfect Day milk, Memphis meats and the Impossible Burger. Genetic technologies in plants also have the potential to assist with reduction in nitrogen requirement (Liu *et al*., 2015; Parsons *et al*., 2016) and in subsequent methane production (e.g., Agresearch's high lipid forage grass).

Futures

Genetic technologies might be part of the answer, but so is smart farming, as indicated in the range in the nitrogen loss data. At Oraka Farms in the Waikato, a high input system milk production is approximately 3 times the district average, whereas N-loss is half that of the district (calculated by Fonterra using OVERSEER). No irrigation is available except through the dairy shed effluent, but supplement is used, as is a wood chip shelter. Twice a year the wood chips are removed and spread on the cropping (maize and annual ryegrass) block; the silage is then fed back to the cows in the shelter. This system involves winter milking, a high stocking rate and low N loss. GHG per hectare will be higher than with a low input system, but per kg of milksolids will be lower (Ledgard *et al*., 2017).

In order to achieve a sustainable future, focussing on the science, ensuring rigour, and keeping facts and feelings separate has been recommended (UK House of Commons, 2017). It is also important to consider whether the alternatives that are being proposed will actually achieve the desired outcome. Picking a solution and working towards proving its worth is common on problem solving (Markham cited in Rowarth, 2017) but doesn't always result in the consequences intended. Further, unless the problem is defined correctly, the likelihood of finding a real solution is slim (Parsons, cited in Rowarth 2017).

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