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Managing greenhouse gas emissions in two major dairy regions of New Zealand: A system-level evaluation

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ABSTRACT

New Zealand dairy farms are responsible for a large proportion of this nation's greenhouse gas emissions (GHG-e), arising mainly from enteric methane and urinary nitrogen deposition on pasture. De-intensification and the use of specific mitigation strategies can reduce GHG-e from dairy farms, but are generally costly. In this study, a farm-level model is used to analyse the cost of GHG-e mitigation strategies in medium- (10–20% imported feed) and high-input (20–40% imported feed) systems in the two major dairy regions of New Zealand (Waikato and Canterbury). Production intensity is measured solely in terms of feed importation, in accordance with standard practice in this nation. The focus of the study is to assess the cost-effectiveness of a variety of de-intensification and mitigation strategies aimed at reducing the negative impact of emissions constraints (reductions of 10, 20, and 30%) on farm profit. De-intensification options include changes in stocking rate, nitrogen fertiliser application, and supplement quantity. Mitigation options include feeding crops, improved reproductive management, use of feed pads, use of stand-off pads, and use of nitrification inhibitors. The model showed that a combination of reduced N fertiliser application and lower stocking rates were the larger changes experienced in the systems studied when GHG-e reductions were introduced. Nitrification inhibitors were only useful for mitigation once the GHG-e reductions required were so stringent that their cost was warranted to offset the significant costs associated with de-intensification in the high-input systems. Stand-off and feed pads were too expensive to warrant their use when not already available. Overall, de-intensification of the farming system proved to be more profitable than the use of specific mitigation practices when reduction of GHG-e was required. Maintaining a given intake of imported feed reduces the degree to which de-intensification may be used for abatement, thus inflating the cost of mitigation strategies on high-input farms.

1. Introduction

The agricultural sector is the largest export earner in New Zealand, being responsible for 60% of merchandise exports by value in 2013 (Statistics New Zealand 2014). The dairy industry is the largest exporter within the agricultural sector, reaching 14.6 billon dollars (51% of the agricultural sector) in this year (Statistics New Zealand 2014). The dairy industry is also the largest employment provider within rural New Zealand, employing around 35,000 workers and up to 25% of the labour force in some parts of the Waikato region. However, at the same time, New Zealand agriculture is responsible for 46% of the total greenhouse gas emissions (GHG-e) of this country (Ministry for the Environment (MfE), 2014).

Dairy farms primarily emit two greenhouse gases (GHG): (1) methane (CH_4) from enteric fermentation in the rumen, and (2) nitrous oxide (N_2O), arising mainly from nitrogen fertiliser application and denitrification of urinary N in the soil. Methane from enteric fermentation is the major source of agricultural emissions in New Zealand (68%) and increased by 8% in the period 1990–2012 (Ministry for the Environment (MfE), 2014). Nitrous oxide from agricultural soils represents 30% of agricultural emissions and increased by 32% in the same period (Ministry for the Environment (MfE), 2014). The main driver of increases in these loadings has been a 27% increase in the cattle population and a 512% increase in nitrogen fertiliser application in New Zealand across 1990–2012 (Ministry for the Environment (MfE), 2014). To be effective, different mitigation options have to be applied to reduce emissions of each of these GHG (Eckard et al., 2010).

Agriculture is included in the New Zealand Emissions Trading Scheme (ETS). However, currently, only large meat and milk processors, fertiliser importers and manufacturers, and live animal

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exporters participate. Livestock farmers are presently not required to surrender entitlements to emit greenhouse gases, and there is no legislated date for this to occur. Indeed, biological emissions from New Zealand farms will only be targeted if trading partners make more progress towards making reductions and economically-viable mitigations are available (Ministry for the Environment (MfE), 2014). Within this context, this study seeks to identify which mitigations are employed, and to what degree, under cost-effective management when different levels of GHG-e restrictions are imposed on New Zealand dairy farms.

Dairy farming is broadly distributed across New Zealand. Waikato has traditionally been the main dairy region of New Zealand, comprising about 30% of the country's herds and around a quarter of the total dairy cows and land within this nation (Livestock Improvement Corporation/DairyNZ (LIC/DNZ), 2013). In comparison, Canterbury is the second-largest region in terms of cow numbers, and has been growing steadily as land is converted from less-intensive sheep farming through the use of irrigation to support higher feed demand. This region accounts for 9% of the national herds and 17% of the country's dairy cows, evidence of the larger average herd size of 789 cows in Canterbury, relative to the average herd size of 323 cows in the Waikato (Livestock Improvement Corporation/DairyNZ (LIC/DNZ), 2013). Given this heterogeneity, this study identifies how cost-effective mitigation strategies differ across contrasting dairy farm systems in the Waikato and Canterbury regions.

A whole-farm model, the Integrated Dairy Enterprise Analysis (IDEA) framework, is used. This non-linear optimisation model provides a comprehensive description of a pasture-based dairy farm in New Zealand and has been demonstrated to accurately replicate farmlet trial information (Doole et al., 2013). Beukes et al. (2010, 2011) evaluated a series of mitigation methods for Waikato dairy farms, but without optimising. In contrast, Adler et al. (2013) used an optimisation model, but only studied 10% GHG-e limits for the Waikato region. This paper extends this work through analysing a much broader range of GHG-e restrictions (up to 30%) and extending the analysis to include both Waikato and Canterbury. Each run incorporates system optimisation with respect to identifying management strategies that maximise profit; the difference between baseline profit in one run and that earned in another once a cap for GHG-e is introduced represents a measure of cost.

2. Methods

2.1. Production system description

Dairy systems in New Zealand are pasture based, with grass directly harvested by the cows generally comprising more than 70% of the cow diet. Seasonal calving is standard, with cows starting to calve as early as the beginning of July in Waikato and the beginning of August in Canterbury, both winter months given New Zealand's placement in the Southern Hemisphere. In Canterbury, pasture growth rates in winter are very low and it is common for cows to graze on crops off-farm during the winter period when they are not lactating (dry). In Waikato, this practice is not as common.

The intensity of dairy production systems in New Zealand is defined according to the proportion of total feed that consists of imported supplement and the time during which this feed is used (DairyNZ, 2012). Production systems 1, 2, 3, 4, and 5 import 0, 4–14, 10–20, 20–30, and 25–50% of total feed offered, respectively (DairyNZ, 2012). Moreover, these systems differ in that imported feed is used to support dry cows only (system 2); late lactation and dry cows (system 3); early and late lactation and dry cows (system 4), and all cows, all year round (system 5).

Four representative dairy farms were studied in this analysis. The first two were medium- and high-intensity farms in the Waikato region, denoted WM and WH, respectively. The second two were medium- and high-intensity farms in the Canterbury region, denoted CM and CH, respectively.

System 3 and 4 farms were used in this study, and are referred to as the medium- and high-input systems, respectively. These two systems were selected because they comprise the bulk of the dairy farms in the represented regions, particularly Canterbury. A feed pad is an area with a hard surface (such as concrete) that is used to feed supplements to the herd from racks or bins. Typically, cows spend less than 5–10% of the day on such structures. These contrast stand-off pads, usually covered with a wood-chip surface, on which animals are typically placed for a high proportion of the day to reduce urine deposition on pasture (Clark et al., 2010). Both permit some reduction in GHG-e, though the mitigation capacity of the stand-off pad is typically greater considering that animals are kept on them for longer, through allowing a proportion of the manure expelled from stock to be managed (stored in ponds before later spraying it onto paddocks), rather than being deposited on pasture. Feed pads were defined in the WH and CH systems since these facilities are commonly used to improve feed utilisation in high-input systems in these regions.

Each modelled farm was defined as a given production system in IDEA, which limited the amount of imported supplement available in the optimisation and when it was fed. Constraints were defined in the optimisation model such that a farm type could not transition to a farm type of lower intensity, even if such dramatic de-intensification was a profitable response to limits placed on emissions. This could have inflated the cost of mitigation, but is deemed a more realistic short-run response, given that management skill, farmer preference, and farm infrastructure are reflected in the intensity of a given farm and represent real barriers to elastic management response to environmental policy.

Information from DairyBase (http://www.dairybase.co.nz), a database used for benchmarking purposes by storing physical and financial data for individual New Zealand dairy farms, was used to define the representative farms for the Waikato region. In contrast, the representative farms in the Canterbury region were developed based on both DairyBase information and expert opinion. DairyBase information could not be used solely for Canterbury farms, given that the data sample was too small to be conclusive. Milk price for this modelling exercise was fixed to \$5.50 per kg of milksolids (MS). Other costs were urea at \$500 t; palm kernel expeller (PKE) at \$350 t of dry matter (DM); and maize grain at \$650 t DM.

2.2. IDEA description

A comprehensive nonlinear programming model of a New Zealand dairy farm – the Integrated Dairy Enterprise Analysis (IDEA) model (Doole et al., 2013)—was used to analyse the impacts of restricting GHG-e and thereby evaluate a broad set of mitigation options. This section provides a concise overview of the model; more detail is provided in Doole et al. (2013).

IDEA identified the feeding strategy that maximised annual profit for a given set of circumstances (e.g. a limit on GHG-e). There were six primary sources of feed available in the model: grazed pasture, pasture silage, maize silage, palm kernel expeller (PKE), maize grain, and turnips. Their availability depended on the region and farm system studied. IDEA determined how much of each of these feeds was provided to the cow herd in a given period. Ten per cent of the farm was re-grassed each year, and nitrogen fertiliser application promoted pasture growth, to a degree that depended on the time and extent of application. Silages, PKE, and turnips complemented pasture intake, and losses during harvesting and feeding were accounted for in the model. Moreover, their feeding compromised pasture intake by substitution (replacement of pasture by