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Modelling the Impact of Policies to Reduce Environmental Impacts in the New Zealand Dairy Sector

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Abstract

Agriculture remains a major sector of the New Zealand economy, with the vast majority of farm and food production exported. The accelerating intensification of farming in New Zealand over recent decades raises concern over the current sustainability of New Zealand farming, and whether it can remain so in the future. In this study, we focus on the impacts of policies to reduce environmental impacts of dairy farming, with a particular focus on nitrogen pollution and greenhouse gases (GHG) emissions. We use a modified version of the Global Trade Analysis Project (GTAP) model and database, with improved specification of the agricultural sector and land-use. We augment the model with environmental indicators for New Zealand, including nitrogen balances and GHG emissions.

We simulate a range of scenarios involving reductions in fertiliser use and stocking rates on dairy farms, from an updated 2010 database. In particular, we consider seven scenarios, with the objective of exploring reductions in the dairy stocking rate and the application of nitrogenous fertiliser to dairy farms to target reductions in the dairy sector's nitrogen balance of 10%, 20% and 30%. Reducing fertiliser use and stocking rates are two of the approaches that dairy farmers can take in order to reduce their emissions of nitrogen and GHGs. Our results suggest that the nitrogen balance could be reduced by 10% with a 16% cut in nitrogenous fertiliser and a 5% fall in the stocking rate. Reducing fertiliser use and stocking rate by 31% and 11% respectively could result in a 20% cut to the dairy sector's nitrogen balance. To achieve a 30% reduction in the nitrogen balance, our results suggest that the cut back in fertiliser use would need to be 45%, with the stocking rate reduced by 19%. Across these scenarios, our results indicate that value added in the dairy farm sector could fall by between 2% and 13%, while export earnings from dairy products may fall by between US$269 million and US$1,145 million.

Keywords

global CGE model

dairy production

environmental impacts

environmental policy

JEL Codes

F14; F17; F18; O13; Q15; Q17 ; Q53 ; Q58

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Introduction

Agriculture remains a major sector of the New Zealand economy, with the contribution of raw agricultural and processed food products to total merchandise exports being over 62% in 2008 (World Bank, 2010). The accelerating intensification of New Zealand farming over recent decades raises concern over the current sustainability of New Zealand farming, and whether it can remain so in the future (MacLeod and Moller 2006). Livestock farming's potential to cause environmental degradation worldwide is now well documented (Steinfeld *et al*. 2006, 2010), including: land degradation; deforestation; climate change and air pollution; water shortage and pollution; and loss of biodiversity.

Livestock's impact on the environment, including on nitrogen balances and greenhouse gases (GHG) emissions, is an important domestic policy issue in New Zealand, since livestock farming accounts for around two-thirds of the value of farm output. It has also become a trade policy issue with the growing trend for foreign buyers and policy makers to place emphasis on 'green' and environmentally-friendly livestock production. Since livestock and their manufactured products contribute around 70% of the country's total agricultural and food exports, failure to adequately respond to foreign market trends poses a risk to the country. There is therefore an imperative for New Zealand to work towards sustainable export-oriented agricultural production.

In this study, we focus on the impacts of policies to reduce environmental impacts of dairy farming, with a particular focus on nitrogen pollution and GHGs. We use a modified version of the Global Trade Analysis Project (GTAP) model and database. This is a very well-documented and extensively used international modelling framework.[1] Using a model that captures international interactions is particularly important given the importance of international markets to the New Zealand dairy sector. However, modelling of the agricultural sector, land-use specification and data in the standard version of GTAP is somewhat limited. Therefore, we make significant modifications to the model and database to improve the specification of the agricultural sector and land-use. We also augment the model with environmental indicators for New Zealand, including nitrogen balances and GHG emissions.

We begin with an overview of our New Zealand-specific data development and the modifications made to the standard GTAP model, before turning to some key environmental indicators modelled - nitrogen balances and GHG emissions. We then explain the baseline developed, before turning to analyse some key the potential impacts of a range of alternative policy scenarios and making some tentative conclusions.

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[1] See Hertel (1997) for the base theory and description of the model and www.gtap.org for updated details of the model and database.

1 Improved Modelling of New Zealand Agriculture[2]

1.1 Background

Since much of New Zealand's farm output is eventually sold in foreign markets, analyses of the future development of this sector in New Zealand, and consequent environmental impacts is perhaps best conducted within a global setting. For the same reasons, analyses of New Zealand's policy responses to environmental developments should also be conducted within a global framework, since such policies may impact on New Zealand international agricultural competitiveness and export performance.

Earlier global CGE modelling for New Zealand agriculture and environmental analysis used the standard GTAP model. Cassells and Meister (2001) used GTAP to examine dairy nitrogen leaching and water quality, while Rae and Strutt (2001) focussed on nitrogen pollution from livestock farming, using gross nitrogen production from livestock effluent as a proxy for the nitrogen surplus. The latter modelling indicated that growth and structural change over time were of much greater consequence as a driver of environmental damage than trade reform, with multilateral trade reforms sometimes having positive impacts on the global environment. The analysis was further developed by Rae and Strutt (2007), using nitrogen balance data from the OECD in place of gross nitrogen production from livestock and modifying the standard GTAP model through incorporation of additional substitution relationships in farm production. Agro-chemicals were allowed to substitute for land in crop production, purchased feeds able to substitute for land in livestock production, and substitution was permitted among individual feedstuffs in livestock production. This facilitated modelling the impacts of trade liberalisation on the intensity of agro-chemical use in agriculture as an additional environmental indicator.

The current study builds on our previous work, with significant improvements to land-use modelling and more flexible modelling of the agricultural sector, along with updated and extended economic and environmental databases.

1.2 Improved land-use modelling

Land quality and value play an important role in determining how landowners allocate land among uses and hence the greenhouse gas and nutrient emissions that result from the various land types and use activities. While the standard GTAP model recognises a single land type, recent research has developed a land use and land cover database to permit a much more refined characterisation of the potential for shifting land use among cropping, livestock and forestry activities (Lee et al. 2005; Ramankutty *et al*. 2007).

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[2] This and the following section draw on documentation from an earlier version of the model development, as described in (Rae *et al.*, 2009).

1.2.1 Agroecological zones and GTAP land use data

The GTAP land use database is built on the agroecological zoning (AEZ) research of FAO and IIASA (Fischer *et al*. 2002). AEZ refers to the segmentation of a parcel of land into smaller units according to agroecological characteristics such as moisture and temperature regimes, along with length of the growing period. In this way the heterogeneity of land is taken into account. Thus, in the model, competition for land within a given AEZ across uses is constrained to include only activities that have been observed to take place in that zone. If two land uses do not appear in the same AEZ, then they will not compete in that land market.

As documented in Rae *et al*. (2009), concerns exist over the way the GTAP land-use database covers pastoral land, which is of particular significance for New Zealand. In particular, the SAGE database was the original source of total land areas but ‘pastoral’ land was not divided into that used by the various pastoral livestock activities, such as sheep farming, beef raising or milk production. Therefore in the GTAP land-use database for New Zealand, the distributions across AEZ’s of the market value of pasture land used in the ruminant cattle and in dairy cattle sectors were identical. This is clearly incorrect. Furthermore, the AEZ concept is not commonly used in New Zealand, so an alternative land environment database has been constructed that seems much more appropriate to use for New Zealand (Rae et al., 2009). Given that the land use data are superior in this new database, and that using the same definitions as other New Zealand scientists is likely to improve communication and collaborative research opportunities, we therefore opted to replace the AEZ data in the GTAP database with that derived from New Zealand’s own land environment classification.

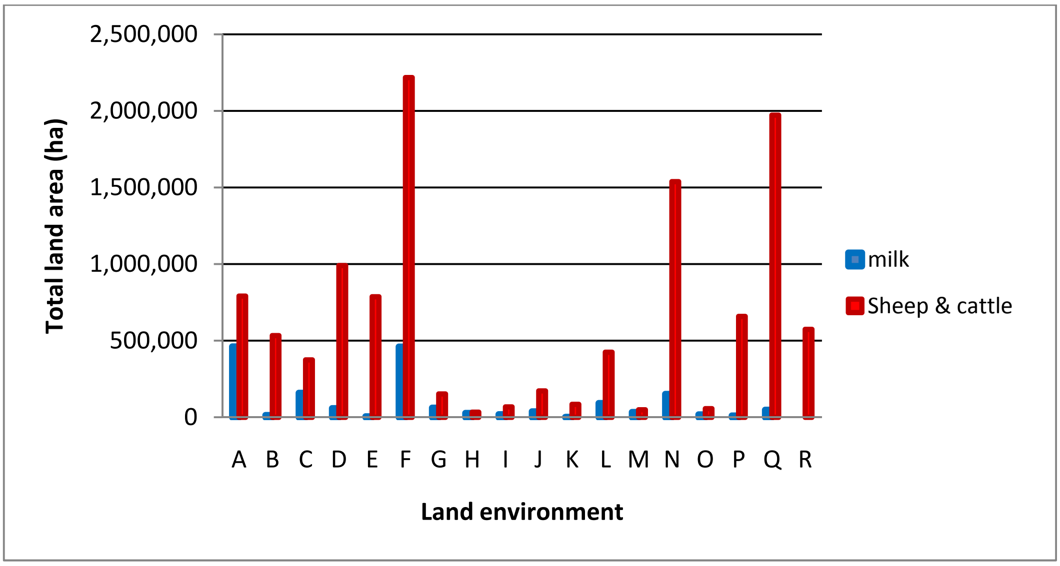
1.2.2 Land environments of New Zealand and land use

The land environments of New Zealand (LENZ) classification was developed by a large team of scientists including several from Landcare Research, one of New Zealand’s Crown Research Institutes, and the Ministry for the Environment (Leathwick *et al*. 2003). LENZ is a classification of New Zealand’s landscapes using a comprehensive set of climate, landform and soil variables. Although these variables were primarily selected for their role in driving geographic variation in indigenous ecosystems, they also have wide application for land use management in agriculture, horticulture and forestry, since the variables that influence indigenous systems also strongly constrain the productivity of crop species. LENZ is presented at four levels of detail containing 20, 100, 200 or 500 environments: we use the first level of 20 environments. A total of 15 variables were used to define the environments, including annual and winter minimum temperatures, annual and winter solar radiation, annual water deficit and monthly water balance (rainfall/potential evaporation), soil slope and drainage, and chemical composition of the soil. Unlike AEZs, these do not explicitly incorporate the length of the growing season (degree days), although total degree days could be calculated from the underlying data if required.

Within each of the 20 environments, data were available on the total area of land and the distribution of that land over geographic regions in New Zealand. From other New Zealand sources we obtained land use data (essentially horticulture, other cropping, sheep, beef and deer farming, dairying and production forestry) by the same geographic regions. Overlaying these two databases (LENZ and land use) the total area of land, by land use classification, was obtained for each of the environments.

Figures 1 and 2 provide information on land use by the major pastoral farm activities. The definitions of the various environments are found in Appendix Table A1. Sheep, beef and deer farming uses a greater share of land within each environment than does dairy farming, especially in the northern hill country, central drylands and foothills and the mountainous environments of the South Island. In terms of total land use, dairy farming was primarily found in the northern lowlands (much of Northland, South Auckland and Waikato), the central hill country (which includes much of Taranaki), western and southern North Island lowlands (Manawatu and part of Taranaki) and the eastern South Island plains. Sheep, beef cattle and/or deer farming was a major land use in the central hill country, eastern South Island plains and the south- eastern hill country and mountains of the South Island.[3]

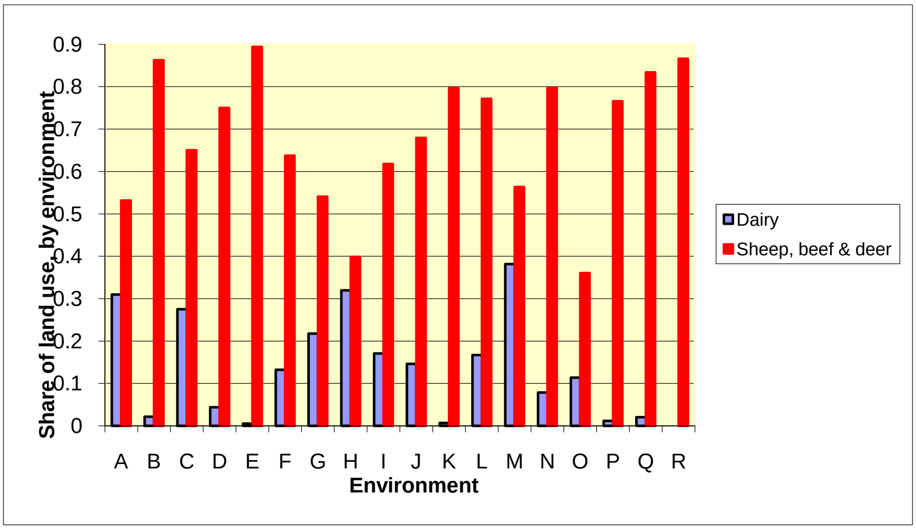
Figure 1. Distribution of livestock across land environments: 2003



Source: Landcare Research.

3 We note these data refer to the 2003 year: since then dairy farming has expanded relative to other pastoral land use especially in eastern and southern regions of the South Island.

Figure 2. Share of land use by livestock farming type: 2003



Source: Landcare Research.

To use these data within GTAP, the land area data by farm activity and environment has to be converted to rental values. On the assumption that land rentals are proportional to land values, we obtained official land valuations per hectare by land use and the same geographical regions (77 Territorial Authorities) that were used above.[4] These were then applied to the land use by environment data.[5]

It is of interest to observe how the share of land used in some farm activity within any environment varies across environments (see Appendix Table A2). For example, dairy production tends to occur in environments with mean annual temperatures between 10-15^{0}C, and on relatively flat land. Some sheep and beef production occurs under similar environments, but is also found in cooler and steeper environments (Rae et al., 2009).

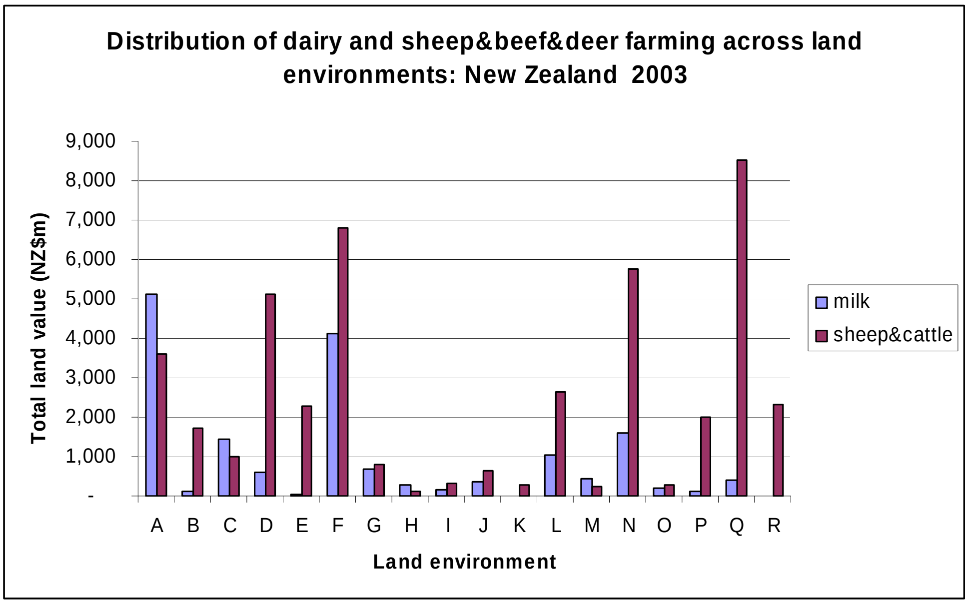
Figure 3 shows how the total valuation of pasture land used in sheep, beef and deer production, and that used for dairying, are distributed across the land environments. These distributions are quite different, but they are assumed to be the same in the GTAP-AEZ database, further supporting our decision not to use this database for New Zealand. While environment F (Central Hill Country) is important for both farm activities, environment A (Northern Lowlands) is relatively more important for dairy, while the reverse holds for environments D (Northern Hill Country) and Q (Southeastern Hill Country and Mountains). Figure 3 also differs from the land quantity data of

4 We gratefully acknowledge that these valuation data were provided through the FRST-funded Motu project 'Integrated Economics of Climate Change'.

5 See (Rae *et al*., 2009) for further details of this approach developed for version 6 of the GTAP model. In the current study, we update the land data to enable use of version 7 of the GTAP database.

Figure 2, as the former reflects the higher average per hectare values of dairy versus sheep/beef/deer land.

Figure 3. Distribution of livestock across land environments, by value



Sources: Landcare Research, MOTU.

2 Modifications to the Standard GTAP model and Databases

2.1 Database modifications

Our new land use data is used to substitute for the New Zealand AEZ values in the GTAP land use database. We omit environments S and T that were specified in the original dataset, since they support very little agricultural land use. This leaves us with 18 classes, conveniently the same as the number of AEZ classes used for all other regions in the GTAP database. Care must be exercised to ensure that various balance conditions in the original GTAP database (such as the sectoral zero profit conditions) are not disturbed by this data substitution. In the GTAP Land Use Data, AEZ values are given for three variables that represent available supplies of land in each environment, and use of land in each environment by farming type. Our new data must therefore replace the AEZ values in each of these variables for New Zealand. In order to maintain balance conditions in the GTAP database, we adjusted our new land value data in the following way. This procedure is followed for each of the above GTAP variables.

Let $h_{k,j,NZ}$ be the total area (ha) used by sector j in the kth New Zealand land environment; $v_{k,j,NZ}$ be the value ($/ha) of land of type k used by sector j; and let $lv_{k,j,NZ} = h_{k,j,NZ} * v_{k,j,NZ}$ be our new land value data for the New Zealand land environment k and the land-using sector j. Now let $aez_{k,j,NZ}$ be the original AEZ data in the GTAP land use database, for AEZ class k in land-using sector j in New Zealand. The $lv_{k,j,NZ}$ data for New Zealand are adjusted by a constant so that the summation of these data over all environments for each sector, is identical to a similar summation of the $aez_{k,j,NZ}$:

$$lv^*_{k,j,NZ} = lv_{k,j,NZ} * \sum_k aez_{k,j,NZ} \;/\; \sum_k lv_{k,j,NZ}$$

This makes clear how our procedure has improved upon the New Zealand data available in the GTAP AEZ database. First, we have land-use area data for both dairy and sheep/beef pastoral farm activities ($h_{k,j,NZ}$), whereas GTAP only has total pastoral area; and second, these area data by environment are valued using environment and farm use-specific valuations, whereas GTAP uses a common average price over all AEZ environments.

2.2 GTAP model modifications

A number of modifications to the standard GTAP model are made to accommodate the AEZ data and develop a more appropriate specification of the agricultural sector. The data and structure of the standard GTAP model (Hertel, 1997) are modified in a number of significant ways. The first modifications follow Rae and Strutt (2007). In particular, we allow input substitution possibilities between land and agricultural feedstuffs, as well as between land and fertiliser. The second key innovation of the current study is to incorporate eighteen different land types, including new data developed for New Zealand.[6]

Error! Reference source not found. presents an overview of the modifications made to the standard GTAP production structure. The first modification, which allows additional input-substitution, is guided by the approach of OECD (2005, chapter 6). Fertiliser is permitted to substitute for land in crop and livestock production, and purchased feedstuffs can substitute for land in livestock production. Substitution among individual feedstuffs in livestock production is also modelled, unlike in the standard GTAP model. Constant Elasticity of Substitution (CES) elasticities (taken from OECD 2005) are specified to be 0.1 between fertiliser and land and 0.4 between purchased feeds and land for the livestock production sectors. We use a value of 0.9 for the CES feedstuffs substitution elasticity for livestock sectors, being a share-weighted average derived from the elasticities of substitution estimated by Surry (1990). Substitution between capital and skilled and unskilled labour is modelled with CES elasticities set equal to those from in the value-added nest in the standard GTAP formulation. Finally, some substitution is allowed between the capital-labour-natural resources composite and the land-fertiliser-feed composite, with a CES elasticity of 0.1 (OECD, 2005).

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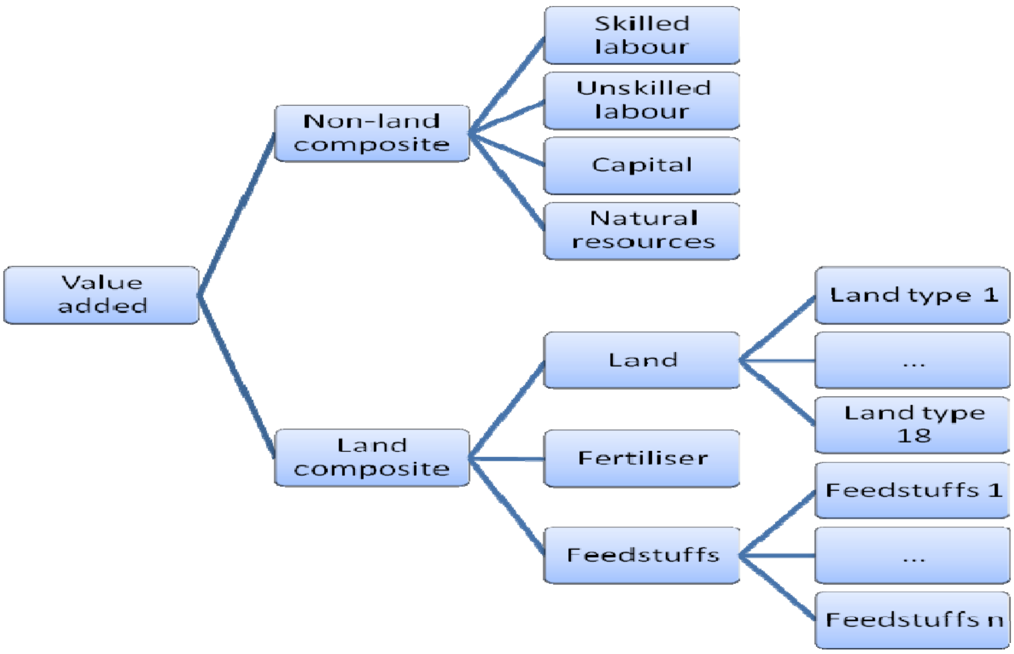
[6] We use the GTAP v7 database, but at the time of preparation of this report, AEZ data were only available for v6. Therefore, we applied the proportional land values by sector and region in GTAP v6 AEZ to v7 as an approximation for all regions apart from New Zealand.

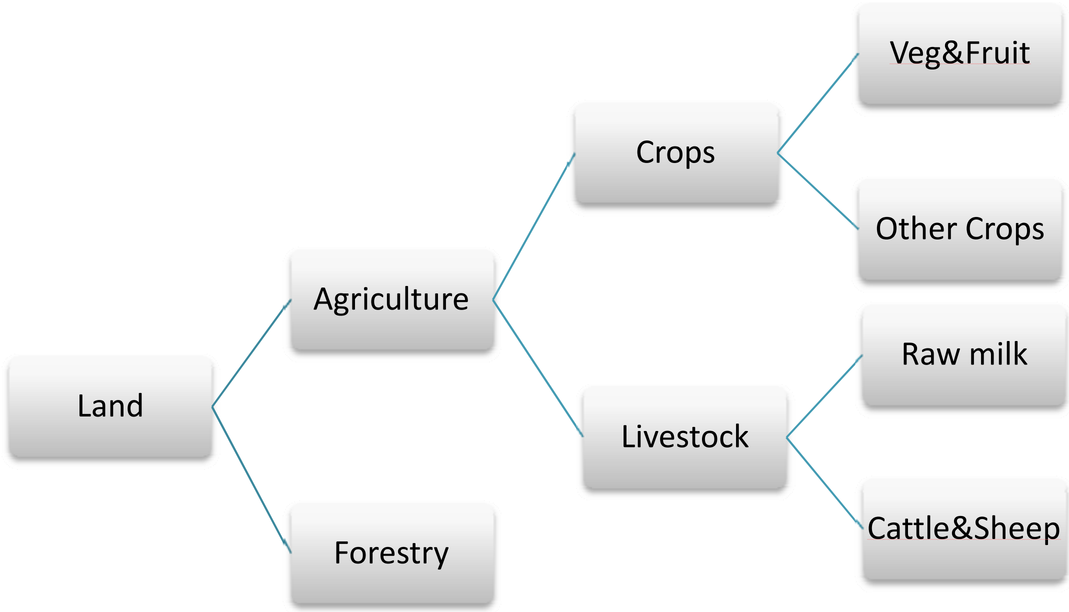
The second key modification is to incorporate the different land types described above, which involves adding a new nested CES function. This allows substitution between different land types to form a land composite. Following the work of Golub, Hertel and Sohngen (2008), we set the elasticity of substitution among different land types in production to 20, except for forestry, where the CES is much lower at 0.4. Relatively high elasticity of substitutions will cause the return to land across AEZs, but within a given use, to move closely together (Golub, Hertel and Sohngen 2008). Land mobility is constrained using a Constant Elasticity of Transformation (CET) frontier, following the treatment of sluggishly mobile factors of production in the GTAP model (Hertel 1997). The larger the absolute value of the CET parameter, the more mobile land; the closer to zero is the CET parameter, the more unresponsive changes in land use are to changes in relative returns from different activities (Golub, Hertel and Sohngen 2008). We model transformation possibilities for land at three levels, as summarized in Figure 5. Between forestry and agriculture, the CET is -0.2, between crops and livestock it is -0.3. Between different crop types and between grazing commodities, the CET used is -0.5.

Figure 4. Modified Production structure in GTAP-ENZ (with CES functions to define substitution possibilities)[a]



[a] Note that value added in this figure includes land augmenting intermediate inputs.

Figure 5. Allocation of each land type to sectors in GTAP-ENZ (CET elasticities)



Modelling Agriculture's Nitrogen and GHG Emissions

2.3 Modelling GHG emissions

Our approach to GHG emission measurement is limited by the output variables of our projected database. These do not, for example, include details of changes in livestock numbers and types. What we are able to project are changes in land usage by farm sector, changes in sectoral demands for fertiliser (proxied by the GTAP chemicals sector which includes fertilisers) and changes in capital usage by farm sector (which for pastoral sectors would include livestock capital). Making an assumption that changes in pastoral sectors' usage of capital are a reasonable proxy for changes in livestock numbers, we first allocate the base period GHG emissions to those due to changes in land area, fertiliser inputs and livestock numbers (Table 1).

Next, GHG base emissions under each functional group of **Error! Reference source not found.** are assigned to the farm sectors of the GTAP model, then aggregated to the farm sectors we use in GTAP-ENZ. Table 2 details these data.[7]

[7] We acknowledge the assistance of Robbie Andrew (Landcare Research Ltd) in providing these data.

Table 1. Sources of GHG emissions

UNFCCC category	Functional group
Anaerobic lagoon (N2O)	Livestock
Solid storage and dryplot (N2O)	Livestock
Other management systems (N2O)	Livestock
Direct soil (animal waste) (N2O)	Livestock
Animal production (grazing animals) (N2O)	Livestock
Enteric fermentation (CH4)	Livestock
Manure management (CH4)	Livestock*
Leaching (manure) (N2O)	Livestock*
Deposition (manure) (N2O)	Livestock*
Direct soils (fert) (N2O)	Fertiliser
Leaching (fert) (N2O)	Fertiliser
Deposition (fert) (N2O)	Fertiliser
Field burning (N2O)	Land
Field burning (CH4)	Land
Savannah burning (CH4)	Land
N-fixing crops (N2O)	Land
Crop residues (N2O)	Land
Histols (N2O)	Land

* In these three categories there are some emissions resulting from use of pig and poultry manure on crops. These are assigned as functions of land area.
Source: Robbie Andrew, Landcare Research Ltd.

Table 2. Base period (2004) NZ's Agricultural GHG emissions (Mt CO2-e)

Sector	Livestock	Fertiliser	Land	Total
Vegetables & Fruit	0	0.08	0.10	0.18
Other Crops	0	0.11	0.12	0.23
Raw Milk	12.78	1.18	0	13.96
Cattle & Wool	20.76	0.57	0	21.33
Other Animal Products	1.42	0.03	0	1.45
	34.96	**1.97**	**0.22**	**37.15**

Finally, the projected change in GHG emissions is calculated as:

$$chghg_i = \sum_j chq_{ij} b_{ij} / 100$$

where $chghg_i$ = change in GHG emissions from GTAP sector *i*
chq_{ij} = percentage change in sector *i*'s demand for livestock, fertiliser and land
b_{ij} = base period emissions of sector *i* due to driver *j* (the values in Table 2).

2.4 Livestock and nitrogen pollution

Data from the OECD Soil Surface Nitrogen database (OECD 2001) provides us with nitrogen emissions data for our base year of 2004. These are given in. The major nitrogen input is from livestock manure, followed by that from biological nitrogen fixation (BNF) and fertilisers. On the output side, livestock again play the dominant role through pasture consumption. The nitrogen balance is the difference between nitrogen inputs and outputs, and was about 590,000 tonnes in 2004, or 47 kg N/ha. From the OECD database we obtained directly the nitrogen data related to total crop output and total pasture consumption. We then allocated those values across the relevant sectors in GTAP-ENZ, for example by basing dairy cattle consumption on that sector's share of total livestock units in New Zealand in 2004.

Manure nitrogen inputs were taken directly from the OECD source. For fertiliser inputs, the OECD database provided the total for all agriculture. External data were used to allocate fertiliser use across our farm sectors – for example, from dairy industry sources we obtained the average farm application rate of N fertiliser per hectare in 2004, and multiplied that by the total area of land in dairy farming. The biological nitrogen fixation input was allocated across pasture-using sectors using the area of pasture used in dairy and other livestock farming, and an assumption that the rate of BNF/ha on pasture used for dairying is twice as great as that on other pasture land.

We estimate changes to the New Zealand (or dairy) nitrogen balance by combining selected solution values from GTAP-ENZ with the base data in Table 3. Nitrogen outputs from the Vegetables & Fruit and Other Crops sectors are assumed to change in proportion to the change in harvested outputs of those sectors. Nitrogen outputs due to pasture consumption are assumed to change in proportion to the change in animal numbers in the Raw Milk and Cattle & Wool sectors. Changes in nitrogen inputs from manure are calculated using changes in animal numbers in the Raw Milk, Cattle & Wool and Other Animal Products sectors. For fertiliser, changes in the demands for fertiliser in each farming sector drive the change in the nitrogen input from fertiliser – this assumes that the demand for N-fertilisers changes in proportion to the change in total demand for all fertilisers. GTAP-ENZ estimates changes to the area of pasture used for dairy cattle as well as for other livestock, and this information is used to project changes to biological nitrogen fixation.

Table 3 Nitrogen Inputs and Outputs in NZ Agriculture: 2004

Output or Input	Nitrogen ('000 tonnes)	Total
Crops		
Vegetables & Fruit	9.3	
Other Crops	13.2	22.5
Pasture Consumption		
Raw Milk	469.9	
Other	1258.5	1728.4
Total Output		**1750.9**
Manure		
Raw Milk	514.7	
Cattle & Wool	954.4	
Other Animal Products	64.9	1534.0
Fertiliser		
Vegetables & Fruit	16.0	
Other Crops	12.0	
Raw Milk	190.0	
Cattle & Wool	130.0	348.0
Biological Nitrogen Fixation		
Raw Milk	96.9	
Cattle & Wool	336.7	433.6
Atmospheric Deposition	25.2	25.2
Seed and Plant Material	0.5	0.5
Total Input		**2341.3**
Balance		**590.4**

Source: OECD Nitrogen Balance Database.

3 Model Baseline

The international economic database we use is GTAP v7, with a base year of 2004 (Narayanan and Walmsley 2008). Therefore, we first project a baseline scenario from this benchmark year to 2010, with various policy scenarios then able to be examined relative to this updated base.

3.1 Baseline macroeconomic assumptions

In the baseline scenario, we project the GTAP database from its benchmark 2004 through to the year 2010. Assumptions are made about a small number of macroeconomic variables, following the innovative path commenced by Hertel *et al.* (1996). In particular, exogenous shocks to each region's endowments of population, skilled and unskilled labour and physical capital are applied, along with productivity increases over this time period.[8] The macroeconomic shocks used to project the database are detailed in Table 4, drawing on data collated by Strutt and Walmsley (2010, forthcoming). Since good estimates of what is happening at the sectoral level are important for our baseline, given our focus on the dairy industry, we incorporate estimates of effective hectares of land use and cattle numbers for New Zealand dairy farming. We also make considerable efforts to appropriately model productivity changes at the sectoral level for the entire world economy in our baseline, as detailed in the following section.

Table 4. Macroeconomic assumptions, cumulative change 2004-2010 (%)

	Population	Unskilled Labour	Skilled Labour	Capital	GDP*
Australia	5.3	9.8	6.8	26.5	22.9
New Zealand	5.0	2.0	-0.7	24.5	19.6
China, HK	3.8	5.9	25.8	71.1	81.7
NE Asia	0.7	3.3	2.9	19.9	21.3
SE Asia	7.4	12.1	34.0	30.4	39.5
South Asia	9.0	11.5	31.1	42.3	48.6
North America	4.7	8.2	6.8	27.7	20.8
C&L America	8.0	7.0	29.8	20.7	25.5
EU27	-0.1	1.4	1.8	17.3	15.6
Rest of Europe	1.1	4.3	11.2	18.9	35.5
Rest of the world	11.9	15.8	23.4	25.5	28.5

* This value is determined endogenously within the model.

3.2 Baseline sectoral productivity assumptions

The assumptions we make on sectoral productivity growth broadly follow the approach of Hertel *et al*. (2006) and Golub *et al*. (2007), with non-agricultural productivity growth based on economy-wide labour productivity growth rates, adjusted for productivity differences across sectors. However, we update the labour productivity differentials rates of productivity growth using the latest available OECD estimates[9] and employ greater sectoral differentiation, following Strutt and Walmsley (2010, forthcoming).

Productivity growth rates in agriculture are derived from Ludena et al. (2007) and Golub *et al*. (2007). Ludena *et al*. (2007) estimate total factor productivity (TFP) growth for crops, and ruminant and non-ruminant livestock production. They find that across many countries productivity growth was faster in non-ruminant than ruminant animal production and often

[8] These macroeconomic projections do not include the impacts of the current global financial crisis. See Strutt and Walmsley (2010, forthcoming) for further analysis.

[9] These provide estimates from 1995-2003, contrasting with previous estimates based on 1970-1990 data.

also higher than that in crop production. Rapid catching-up is also projected for non-ruminant production, where TFP growth is more rapid in developing than in developed countries (Table 5). In the absence of better information, we follow Ludena et al (2007) in setting forestry productivity growth at the average of agricultural growth rates. This 'neutral' assumption will not impact the allocation of land between agriculture and forestry.

Table 5. Annual average agricultural and forestry TFP growth rates (% p.a.)

Region	All crops	Milk-Cattle-Wool (Ruminants)	Other animals (Non-ruminants)	Forestry
Australia & NZ	1.42	0.56	0.92	1.11
China & Hong Kong	1.63	3.66	6.70	1.75
North East Asia	-0.13	0.56	0.92	-0.05
South East Asia	-0.13	-0.83	3.47	-0.18
South Asia	1.13	1.57	3.35	1.23
North America	1.42	0.56	0.92	1.15
Central & Latin America	1.00	1.64	4.94	1.13
EU27	1.42	0.56	0.92	1.10
Rest Europe	1.95	0.65	2.49	1.51
Rest of the world	1.14	0.80	0.15	1.08

Source: Drawing on Golub et al. (2007) and Ludena *et al*. (2007).

The sectoral differentials we use for labour productivity growth rates in non-agricultural sectors are derived from OECD STAN data (OECD, 2005). These data provide estimates of labour productivity in terms of the amount of value added per unit of input.[10] Following the approach of Kets and Lejour (2003), these indexes of sectoral labour productivity growth are averaged across countries.[11] To estimate sectoral differentials, the average growth in labour productivity for each sector is assessed relative to average labour productivity growth. Some sectors experience relatively high productivity growth, particularly some of the manufacturing sectors such as electronics, machinery and motor vehicles. See Strutt and Walmsley (2010) for further details of the sectoral differentials used, which are broadly consistent with the earlier findings of Kets and Lejour (2003). These are implemented for each region by multiplying by the *base* factor productivity growth rate for each region by the labour productivity differentials for each sector. Thus the effective impact of these differentials may vary significantly by region.

[10] Consistent data on hours worked are not available for all OECD countries, therefore, labour productivity is therefore calculated as the ratio of value added at constant price to number of persons engaged (OECD, 2005)

[11] We use a simple average as recommended by Kets and Lejour for this kind of labour productivity data with many outliers and sometimes questionable data quality.

3.3 Baseline for nitrogen balance and GHG emissions

As official data for New Zealand's agricultural GHG and nitrogen emissions for 2010 were not available, we proceeded as follows. Data were compiled for these environmental indicators for the year 2004, as presented in Sections 4.1 and 4.2, so as to match the base year of the GTAP model. Results from the projection described above were next applied to the 2004 nitrogen and GHG base data, allowing those data to be projected to the year 2010. Further simulations can then be applied to the latter data. We projected New Zealand's nitrogen balance to increase from 590,400 tonnes of N in 2004 to 594,700 tonnes in 2010. For GHG emissions, we projected the 2004 value of 37.15 Mt CO2-e to increase to 45.23 Mt in 2010.

4 Policy Scenarios and National Level Environmental Impacts

In this section we explain the policy scenarios modelled and present results, including national level calculated changes in nitrogen balances and GHG emissions under alternative policy scenarios. These calculations are made for both the total agricultural sector and the dairy farm production sector. All results are reported relative to the 2010 baseline described in the previous section.

4.1 Scenarios modelled

We model reductions in the dairy stocking rate and the application of nitrogenous fertiliser to dairy farms in order to target reductions in the dairy sector's nitrogen balance of up to 30%. Reducing fertiliser use and stocking rates are two of the approaches that dairy farmers can take in order to reduce their emissions of nitrogen and GHGs. It is important to note that when we force reductions in one of these variables, such as fertiliser use, we allow the other variable (stocking rate) to adjust endogenously within our model. It turns out that in all cases modelled, reductions in fertiliser use imply reductions in stocking rate, and vice versa.

We can also measure the impact of these changes in farm practice on many other variables. Some of these are farm sector variables such as changes in output, livestock numbers and the area of pasture used for livestock farming. Moving beyond the farm sector, we also model impacts on the volume of dairy exports, the export price received by New Zealand, and the value of net exports of dairy products. We also look at how the above changes in New Zealand dairy farm practices might allow international competitors to increase their dairy product exports at the expense of New Zealand. The consequences of reducing nitrogen balances on farm incomes are proxied by several variables – the change in milk output, the change in the dairy products export price, the value of dairy export earnings and changes in dairy farm sector value-added.

The specific scenarios modelled are to force three alternative rates of reduction in fertiliser use on the model: 10%, 30% and 50%, and four reductions in the stocking rate: 10%, 19%, 27% and 34%.[12]

4.1.1 Changes at the farm sector level

Changing the stocking rate and/or fertiliser quantities applied on dairy farms will be accompanied by other changes to milk production practices, and also to input use and output levels in other farm sectors. These will be driven by relative changes in the prices of farm outputs and inputs, and substitution between inputs as computed within the GTAP-ENZ model. For example, the latter allows purchased feed inputs to substitute to some extent for reductions in either land or fertiliser use and hence to moderate output reductions.

Our model results suggest that increasingly larger reductions in fertiliser use on dairy farms lead to decreases in both dairy cow numbers and dairy land, decreases in stocking rates, increases in the use of purchased feeds per cow and reductions in milk output (Table 6). For example, forcing a 30% reduction in fertiliser use results in milk production falling by almost 12%, a 10% fall in the stocking rate but an increase in use of purchased feed per cow by 9%. Because these results are obtained from a general equilibrium model, they also are accompanied by shifts in resource use across farm sectors in New Zealand (and between farming and the non-farming economy). In this case, the decreased land use in dairying allows land to be transferred to the cropping sectors, as well as to sheep and beef farming. Fertiliser use in each of these sectors increases as does their output.

Table 6. Some implications of reduced N fertiliser on dairy farms (% change)

Variable	10% reduction	30% reduction	50% reduction
Farm output			
Milk	-3.2	-11.9	-25.6
Sheep & beef	0.2	0.9	2.3
Horticulture	0.1	0.4	1.4
Other crops	0.0	0.2	1.0
Livestock numbers			
Dairy cattle	-2.9	-11.0	-23.8
Sheep & beef	0.2	0.9	2.3
Purchased feed per cow	2.8	9.4	17.3
Pasture used			
Dairy	-0.1	-0.5	-2.0
Sheep & beef	0.1	0.7	2.2
Dairy stocking rate	-2.8	-10.4	-21.8

[12] We actually targeted stocking rate reductions of 10%, 20%, 30% and 40%, with the above numbers being the closest the model could get to these targets.

When the dairy stocking rate is reduced, land used in dairying falls, but by proportionately less than the decline in cow numbers (Table 7). Fertiliser use declines on dairy farms but the purchase of supplementary feed per cow increases. Milk output declines, for example by just over 15% when the stocking rate is reduced by almost 20%. These changes in dairy production also impact on other farm sectors: the sheep and cattle and cropping sectors expand in terms of land and fertiliser use and animal numbers, as do the cropping sectors.

Table 7. Some on-farm implications of reduced stocking rate on dairy (% change)

Variable	10% reduction	19% reduction	27% reduction	34% reduction
Farm output				
Milk	-6.9	-15.4	-25.7	-37.4
Sheep & beef	1.6	3.6	5.8	8.2
Horticulture	1.5	3.3	5.4	7.7
Other crops	1.4	3.1	4.9	6.8
N fertiliser on dairy farms	-8.2	-18.0	-29.2	-41.4
Livestock numbers				
Dairy cattle	-12.0	-24.1	-36.5	-48.9
Sheep & beef	1.6	3.4	5.5	7.7
Purchased feed per cow	3.8	6.2	7.4	7.6
Pasture used				
Dairy	-2.2	-5.2	-9.3	-14.9
Sheep & beef	2.2	4.8	7.8	11.1

While our model does not measure farm net incomes, we can estimate the change in the value-added in the milk production sector.[13] Results are shown in Table 8. Our findings suggest that milk sector value-added could decline by as much as 16% from the fertiliser reduction scenarios, but substantially more in the scenarios targeting cuts to stocking rates.

Table 8. Impact on value-added for dairy farms

Variable		Dairy value-added (%)	Sheep & beef value-added (%)
N fertiliser reductions	Associated stocking rate cut		
10%	3%	-1.1	0.1
30%	10%	-5.6	0.5
50%	22%	-16.2	0.9
Stocking rate reductions	Associated fertiliser cut		
10%	8%	-13.7	0.5
19%	18%	-28.4	1.0
27%	29%	-43.2	1.6
34%	41%	-57.2	1.9

13 Calculated here as the percentage change in total returns to factor endowments, including land, labour and capital.

4.2 Impacts on nitrogen balances

Having explained how reductions in fertiliser use and stocking rate on dairy farms impact input use and milk output on these farms, what is the potential effect on nitrogen balances? We first calculate changes to N balances for the agricultural sector as a whole, which includes the consequences of changes in inputs and outputs on cropping and sheep & beef farms. Results are summarised in Figure 6. We find that reductions below base levels in the agricultural sector's nitrogen balance are somewhat more sensitive to cuts in the stocking rate on dairy farms than to fertiliser use reductions. A 30% cut in fertiliser use on dairy farms leads to a 12.5% decrease in the nitrogen balance (Figure 6) while a similar percentage cut to the stocking rate decreases the agricultural nitrogen balance by around 17.5% (Figure 7).

Dairy farmers may be more interested in the impact of their mitigation actions on the N balance of their sector alone, rather than for the entire agricultural sector. These results are also shown in Figures 6 and 7. By reducing fertiliser inputs on dairy farms, the input of nitrogen to the soil is reduced, and the accompanying reduction in cow numbers reduces manure deposition but also pasture consumption (which removes nitrogen from the system). These results suggest that a 30% reduction in the nitrogen balance of the dairy sector can be achieved through cutting nitrogenous fertiliser use by around 45%, or alternatively by reducing the stocking rate by about 30%.

Figure 6. Impact of reduced use of fertiliser on N balances

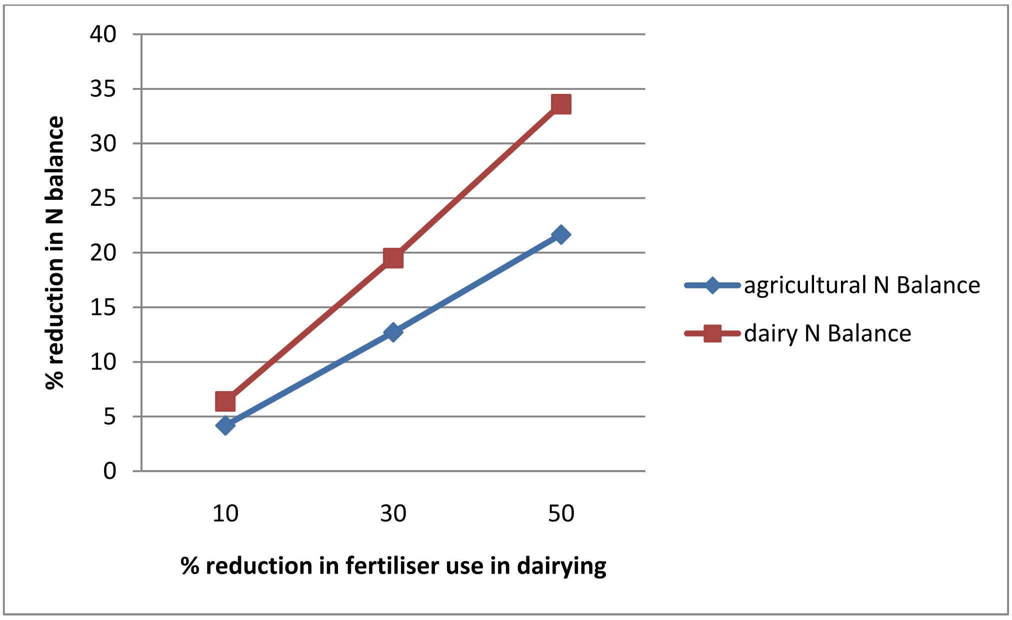
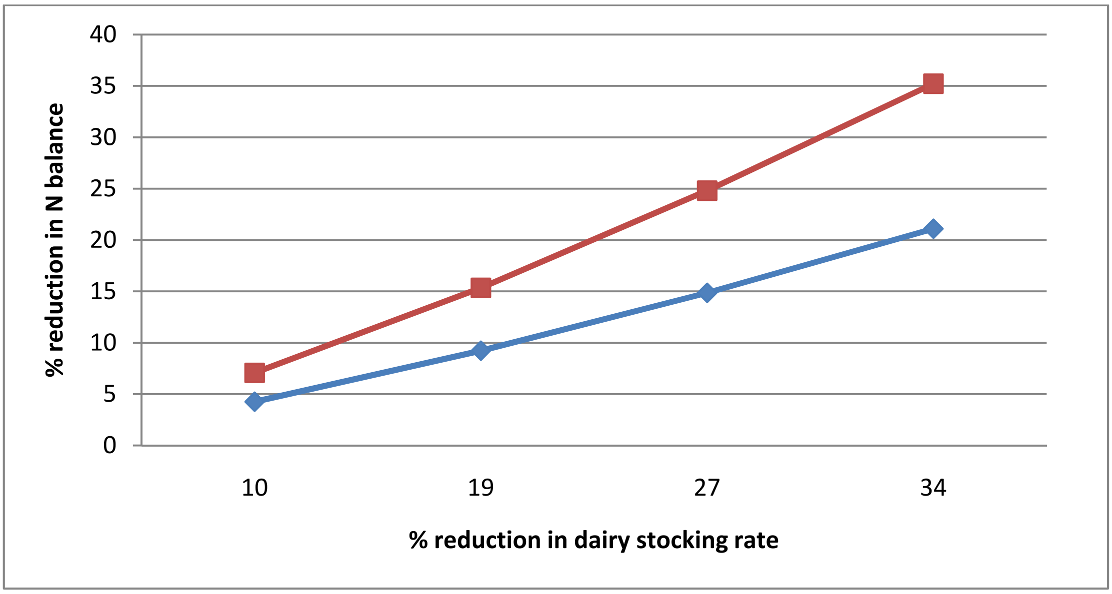


Figure 7. Impact of reduced dairy stocking rate on N balances



4.3 Impacts on dairy exports

A cost of mitigating nitrogen emissions from dairy farming is that of foregone dairy product exports. Our results are summarised in Table 9. We find that impacts on the volume of dairy exports from New Zealand can be quite severe: a 30% cut in fertiliser use translates into an 18% reduction in export volumes, while a stocking rate reduction of 30% sees export volumes declining by over 40%.

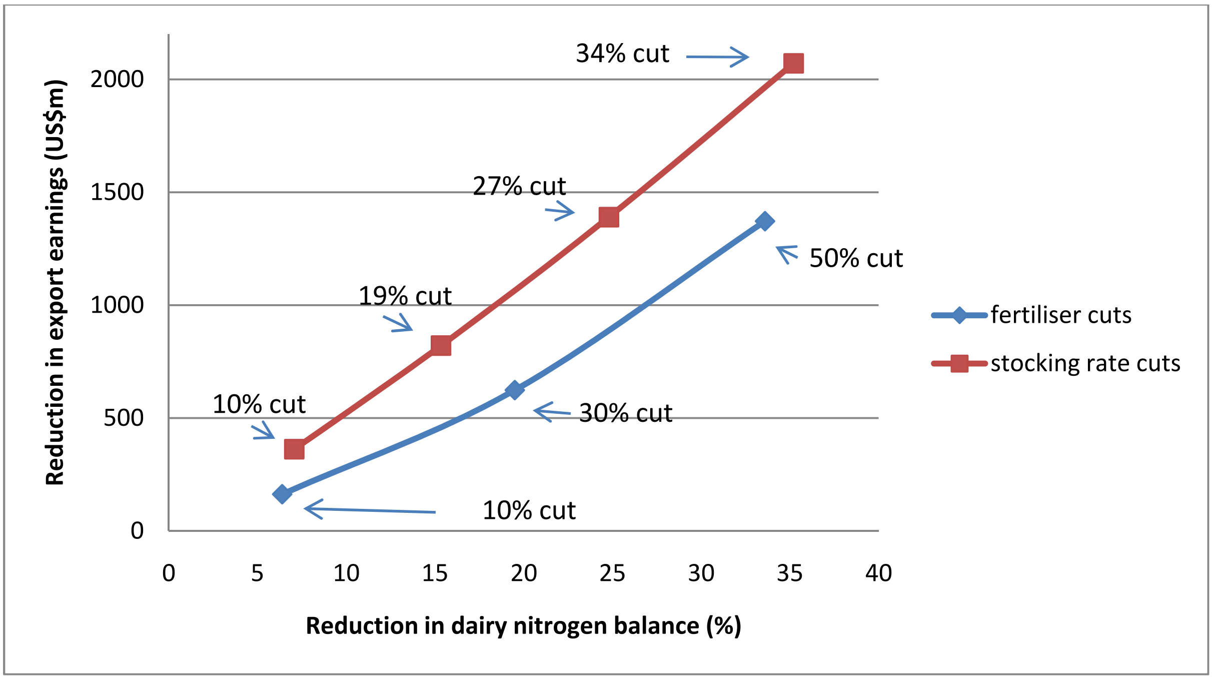
Table 9. Impacts on dairy export volumes, price and the value of exports

Variable		% change in dairy export volumes	% change in dairy export price	Change in net dairy exports (US$ million)
N fertiliser reductions:	Associated stocking rate cuts			
10%	3%	-4.9	0.9	-163
30%	10%	-18.4	3.5	-624
50%	22%	-39.3	8.7	-1,372
Stocking rate reductions:	Associated fertiliser cuts			
10%	8%	-10.7	2.0	-362
19%	18%	-24.0	4.8	-821
27%	29%	-39.8	8.8	-1,390
34%	41%	-57.6	15.1	-2,071

Our calculated changes in the value of New Zealand dairy exports take into account not only the above volume reductions but also any export price change due to the reduced volume of exports. Given that New Zealand has about a one-third share of international trade in dairy products, we might expect the industry to have some power to influence export prices through changes in the volume supplied. We find this is indeed the case, with the export (fob) price received increasing by up to 15% in our simulation experiments. Nevertheless, the reduced export volumes translate into foregone export earnings. For example, we find that a reduction in fertiliser use on dairy farms of 30% could result in the loss of over US$0.6 billion in export revenue; this rises to a loss of almost US$1.7 billion, should the stocking rate be cut by around 30%.

In Figure 8 we combine the impacts of fertiliser and stocking rate cuts on both the nitrogen balance and export earnings. This makes clear that for any given reduction in the dairy sector's nitrogen balance, the loss of export earnings will be minimised (across our seven scenarios) through the use of the fertiliser (and associated stocking rate reductions) given by the bottom-most line. For example, should a 30% cut in the nitrogen balance be targeted, export losses are minimised with a fertiliser cut of about 45% and the associated fall in stocking rate of around 19% (these input reductions can be interpolated from Table 6).

Figure 8. Impact of reducing the N balance on dairy export revenues



Reduced availability of dairy export supplies from New Zealand, and an increase in their price, will provide opportunities for competitors to win market share. Our results suggest that these opportunities are taken primarily by North American and Australian exporters (Table 10), who (depending on the scenario) may increase their total export volumes by up to 11% or 12%.[14] In the Central and South American market for example, New Zealand exports decline by 19% whereas those of competitors increase by 2% to 3%.

[14] These results assume no changes in the policies of countries other than New Zealand.

Table 10.Impacts on competitors' dairy export volumes

Variable		% change in Australian dairy exports	% change in North American dairy exports	% change in EU27 dairy exports
N fertiliser reductions:	Associated stocking rate cut			
10%	3%	0.9	0.8	0.2
30%	10%	3.5	3.2	0.8
50%	22%	7.9	7.1	1.6
Stocking rate reductions:	Associated fertiliser cuts			
10%	8%	2.1	1.8	0.4
19%	18%	4.7	4.2	1.0
27%	29%	8.1	7.2	1.7
34%	41%	12.4	10.8	2.5

Greenhouse gases

Results for GHGs are portrayed in Figures 9 and 10. For the three scenarios that force reductions in fertiliser use, we find that GHG emissions from New Zealand agriculture could fall from between 2% and 10%. Looking at the stocking rate reduction scenarios, GHG emissions may fall by 5% to 15%. Percentage reductions in emissions of greenhouse gases from the dairy farm sector alone are greater, varying from 5% to 30% in the fertiliser reduction scenarios, and from 13% to 55% in the stocking rate scenarios.

Figure 9. Impact of reduced use of fertiliser on GHG emissions

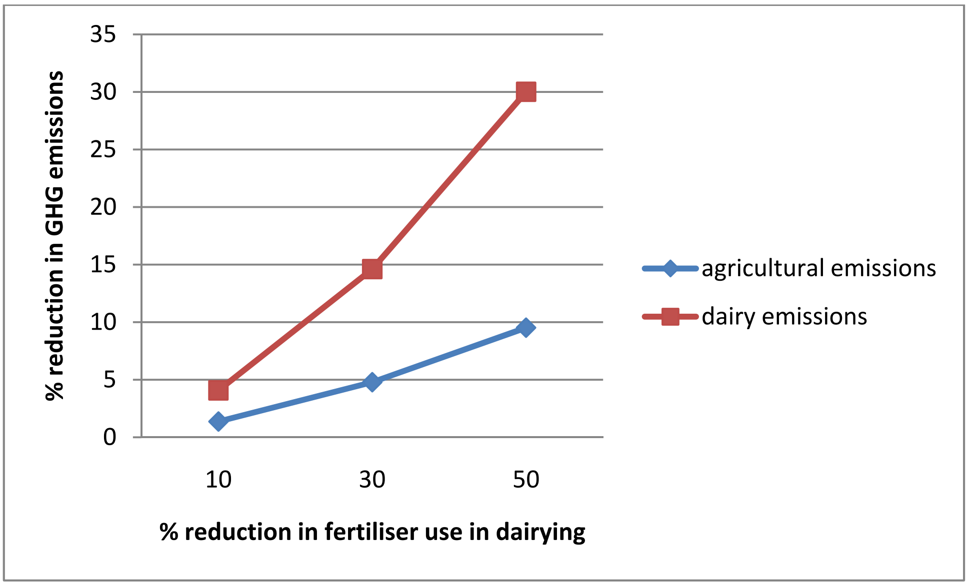
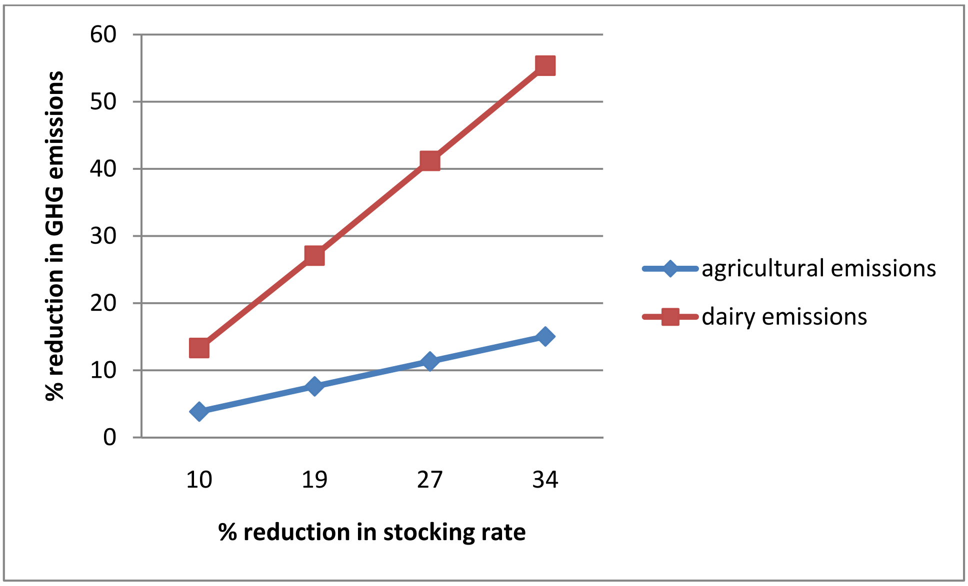


Figure 10. Impact of reduced dairy stocking rates on GHG emissions



5 Concluding Remarks

This report has explained the development of GTAP-ENZ, which builds on the GTAP model and databases to extend and improve analysis of New Zealand agriculture, land use and environmental impacts. This model has been updated to version 7 of the GTAP database, with some significant improvements over the version 6 previously used (Rae et al., 2009), including a benchmark year closer to the current time.[15] We also demonstrate the application of this improved model in analysing the possible farm sector, export and environmental impacts of reducing fertiliser use and stocking rates on dairy farms in New Zealand.

Our research task was to use a global general equilibrium model to help determine potential reductions in fertiliser use and stocking rates on dairy farms that would target reductions in the milk production sector's nitrogen balance by 10%, 20% and 30%. These can be interpolated from the results in the previous section, and are summarised in Table 11. In each case, the foregone producer and export revenues are the least possible from our set of scenarios. Should the nitrogen balance be targeted to fall by 30%, as calculated from our soil-surface nitrogen model, the reduction in fertiliser use on dairy farms would be quite substantial, at around 45%. However, this may not seem so substantial when compared with the increases, and then decreases, in fertiliser use on dairy farms that actually occurred over the past decade. We calculate that such action would lead to loss of production and exports (although a somewhat higher export price) such that net export earnings might fall by up to US$1.1 billion. This is substantial, given that total dairy exports in 2009 were US$5.1 billion.

[15] Longer-term, we would also like to update the New Zealand I-O tables in the GTAP database to reflect our new land valuations by sector. However, this will not be possible until the next release of the GTAP database.

Table 11. Summary results from meeting the target N balance reductions

Reduction in dairy sector N balance (%)	Required cut in N fertiliser use (%)	Associated cut in stocking rate (%)	Reduction in dairy value-added (%)	Reduction in net dairy exports (US$ million)
10	16	5	1.9	269
20	31	11	5.9	645
30	45	19	12.6	1,145

The GTAP-ENZ model developed and used in this study does not endogenise the calculation of environmental indicators in response to policy interventions. Rather, these calculations are performed following the GTAP-ENZ analysis and using external environmental modules. While this is a useful starting point for the policies that we simulate in this study, the same would not apply should we wish to analyse impacts of, for example, an emissions trading scheme. Within an ETS, farmers may be liable for carbon payments depending on whether or not they achieve target emissions levels, and these charges may be reduced through sequestration activities such as forestry. Furthermore, earned carbon credits can be traded nationally or internationally at a carbon price that is determined within the model. We are currently working with Landcare Research staff on a more sophisticated version of the GTAP model (following Golub *et al.* 2010), along with improved environmental data, which will permit improved analyses of this type.

Use of a model that captures international market impacts is important for analysis of a sector so heavily reliant on exports, since the New Zealand dairy industry's market power results in export prices that are likely to change in response to changes in the volume of dairy exports. These export price changes in turn play an important role in determining the payout to dairy farmers and hence the impacts of environmental policies on farm incomes - crucial information for policy makers. However a shortcoming of this and other global models is that they are able to model impacts at only the national level. Therefore there will be an important role for complementary analyses of impacts and policies at a more local geographic level, involving for example regional models of the New Zealand agricultural economy. Simulations such as we conducted can then provide estimates of export price changes resulting from the implementation of environmental policies that could be used as an input into regional models to help determine environmental and income impacts at a more local and disaggregated level. We also note that in the current study, we do not consider the impact of improved environmental technologies, which may have the potential to significantly offset the costs of more stringent environmental policies.

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Appendix

Table A1
Definition of Land Environments

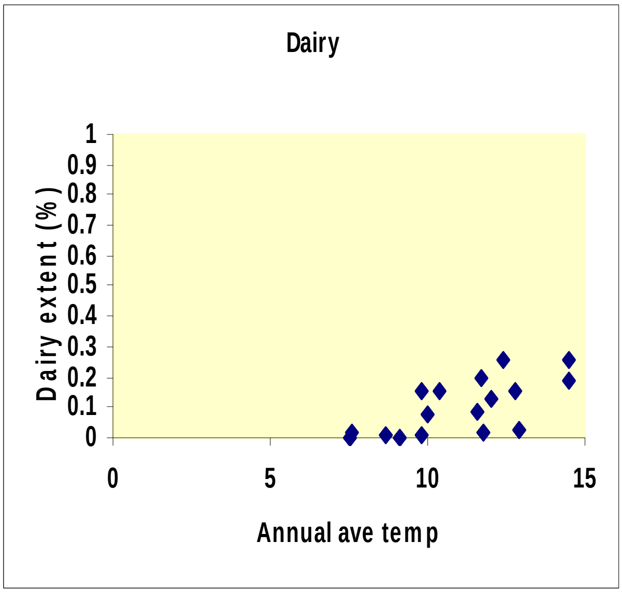
LENZ DESCRIPTION - LEVEL 1		
A	-	Northern Lowlands
B	-	Central Dry Lowlands
C	-	Western and Southern North Island Lowlands
D	-	Northern Hill Country
E	-	Central Dry Foothills
F	-	Central High Country and Volcanic Plateau
G	-	Northern Recent Soils
H	-	Central Sandy Recent Soils
I	-	Central Poorly Drained Recent Soils
J	-	Central Well Drained Recent Soils
K	-	Central Upland Recent Soils
L	-	Southern Lowlands
M	-	Western South Island Recent Soils
N	-	Eastern South Island Plains
O	-	Western South Island Foothills and Stewart Is.
P	-	Central Mountains
Q	-	South Eastern Hill Country and Mountains
R	-	Southern Alps

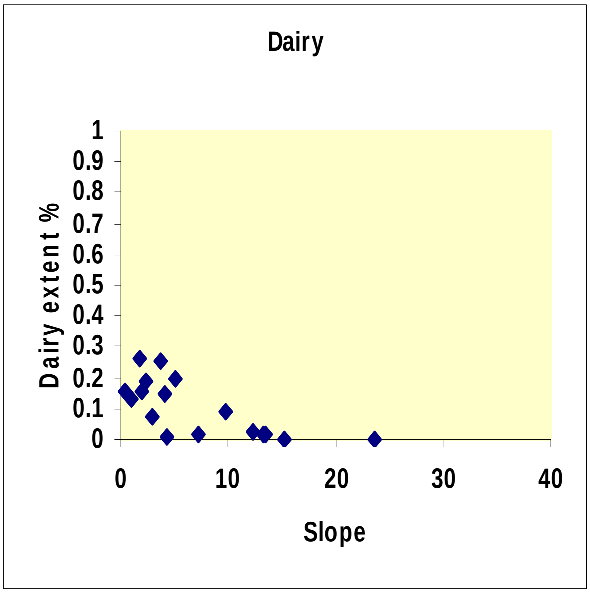
Source: Leathwick *et al*. (2003).

Table A2

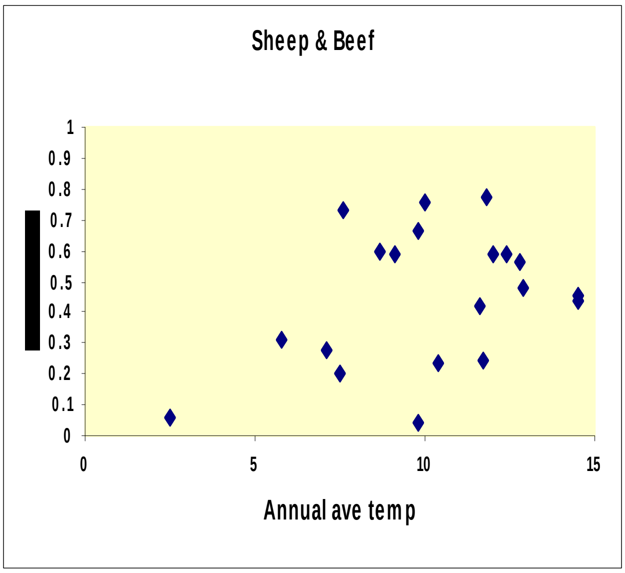
Influence of Environmental Conditions on Share of Land Use

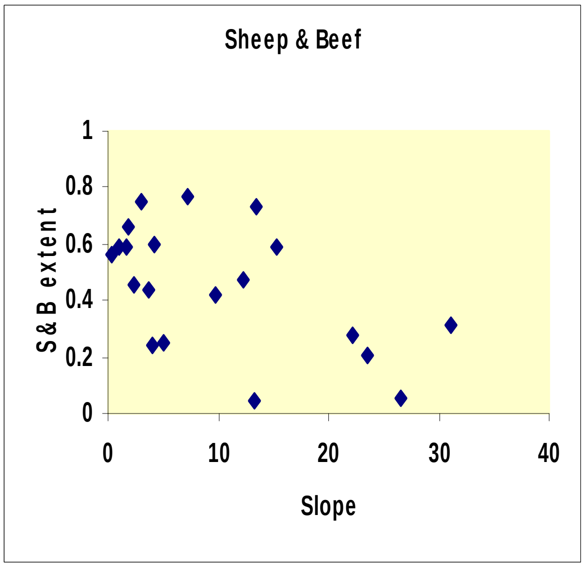
A. Relationships between annual average temperature and slope and extent of dairy pasture: Level I environments





B. Relationships between annual average temperature and slope and extent of sheep & beef cattle pasture: Level I environments





Note: Each marker in the figures corresponds to a particular environment.