Ministry for Primary Industries
Manatū Ahu Matua

ON FARM SUPPORT TEAM

# N, P and C efficient use and circularity in dairy farms in New Zealand


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[2]University of Auckland, New Zealand



The 75th European Federation of Animal Sciences (EAAP) Annual Meeting , Florence, Italy.

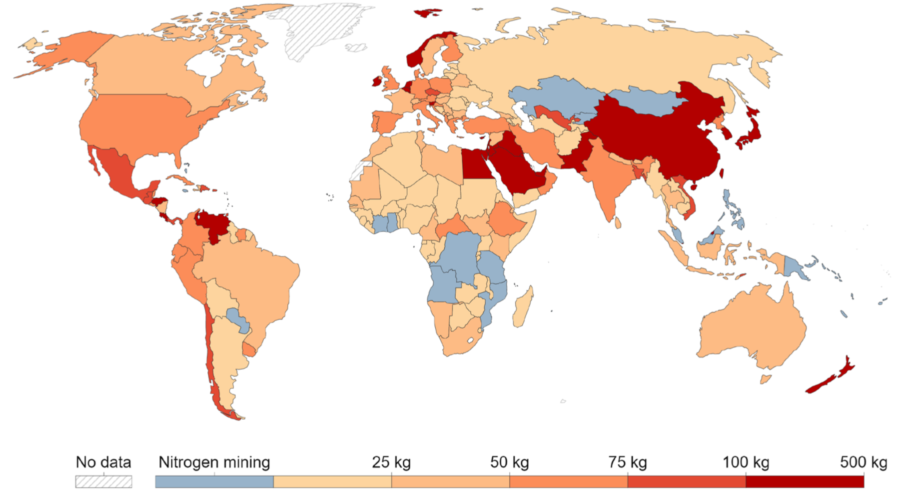
" Eliminate the very concept of waste, not reduce, minimize or avoid waste, but eliminate the very concept by design"

- Prof. Michael Braungart

# We only have one home

## Excess nitrogen per hectare of cropland

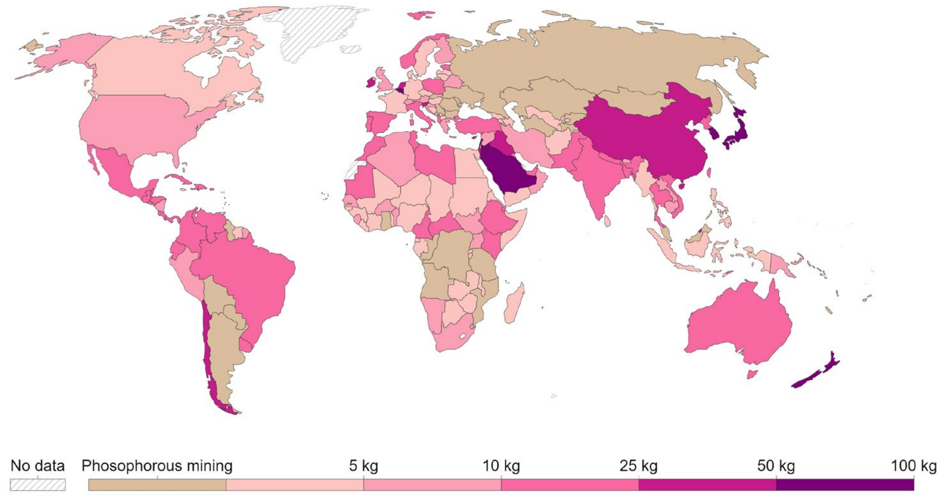
"Excess nitrogen" is the difference between nutrient inputs (from fertilizers, manure, and fixation from legumes) and the amount harvested in crop material. This represents nitrogen that is lost to the environment and can create ecological imbalances in ecosystems and water bodies.




Source: West, Gerber, Engstrom, Mueller, Brauman, Carlson, Cassidy, Johnston, MacDonald, Ray & Siebert (2014). Leverage points for improving global food security and the environment. <i>Science</i>.
OurWorldInData.org/fertilizers • CC BY

## Excess phosphorous per hectare of cropland

Amount of excess phosphorous per hectare of cropland. This is the difference between phosphorous inputs, and the amount harvested in crops.

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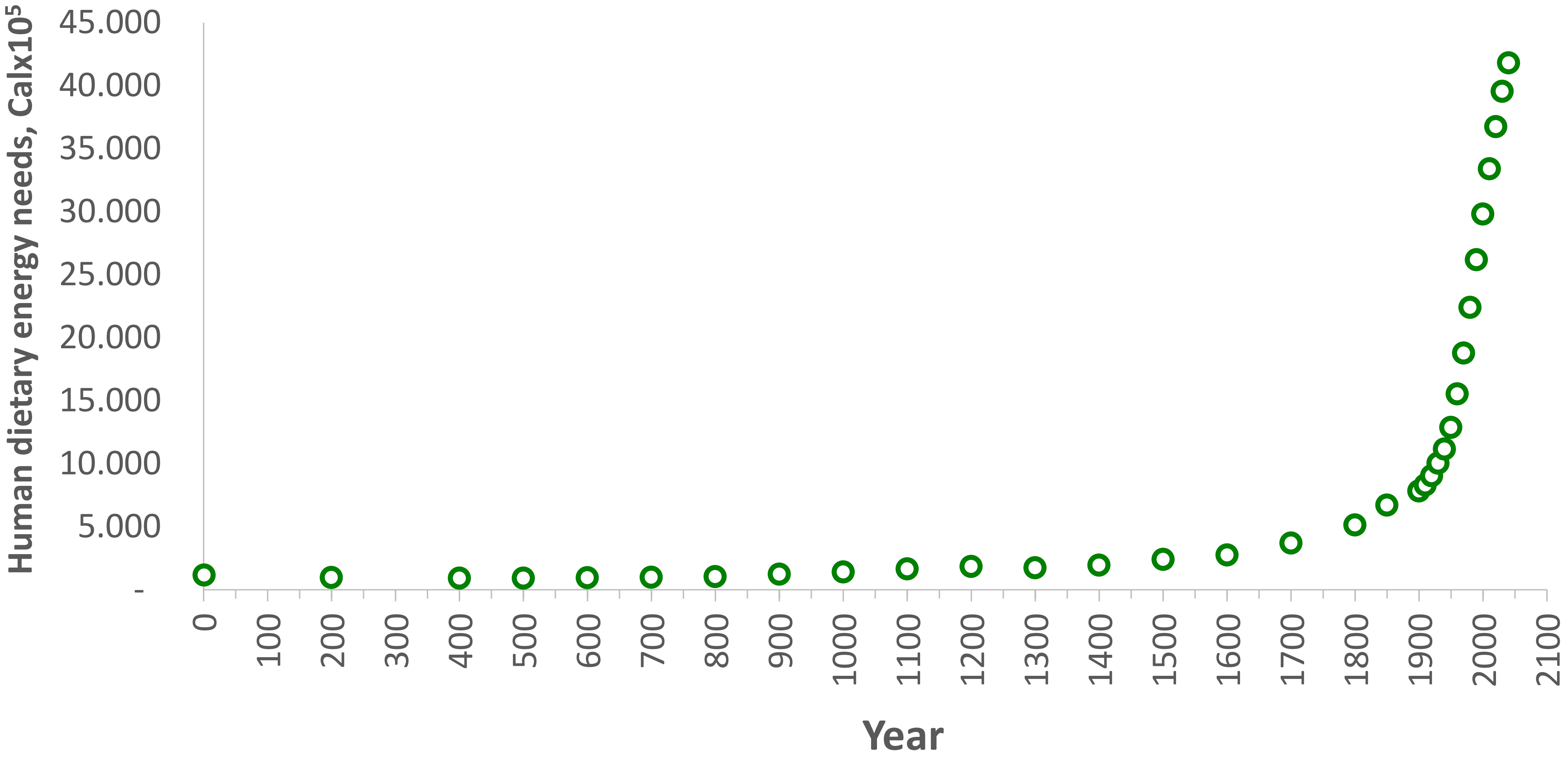
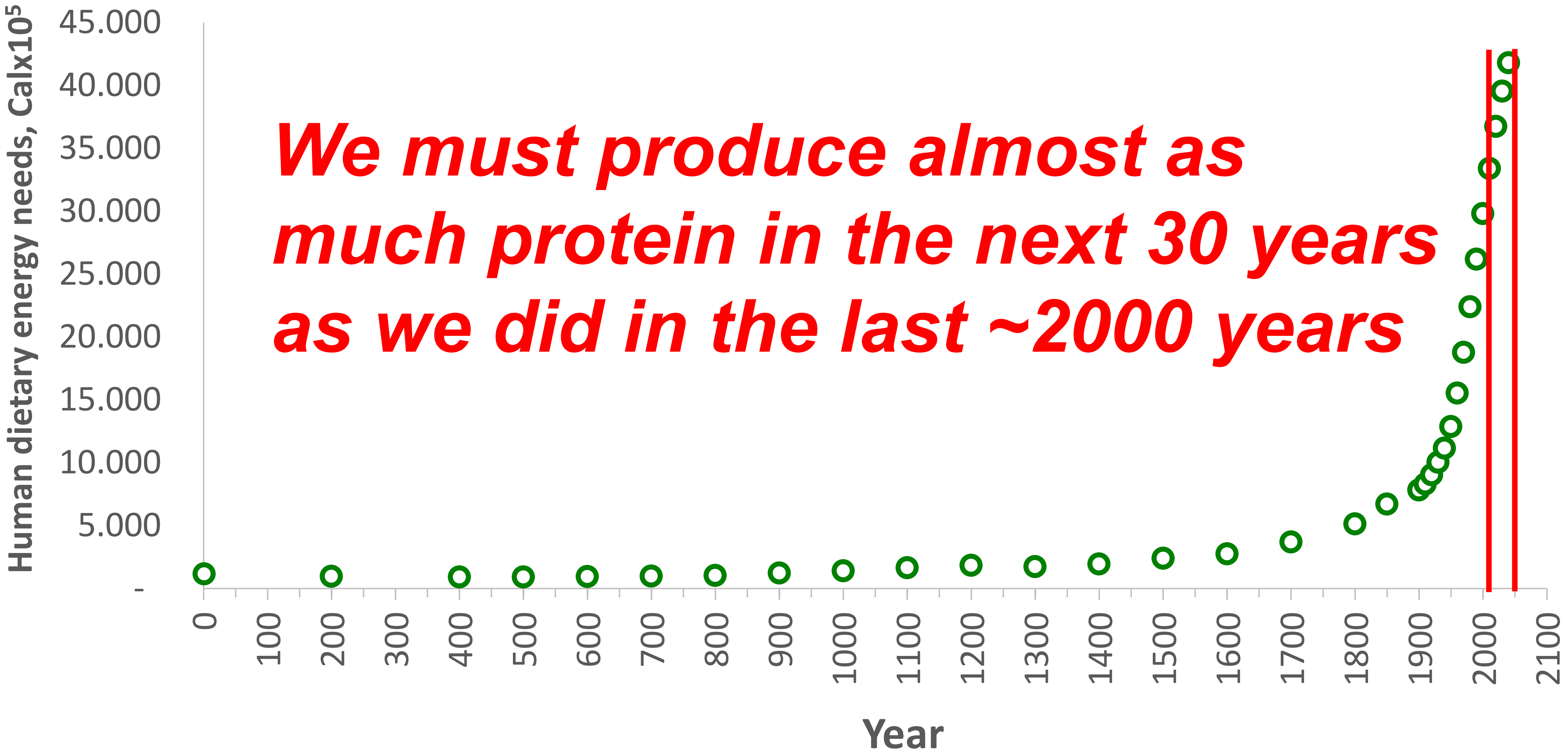
# Humanity has a massive challenge



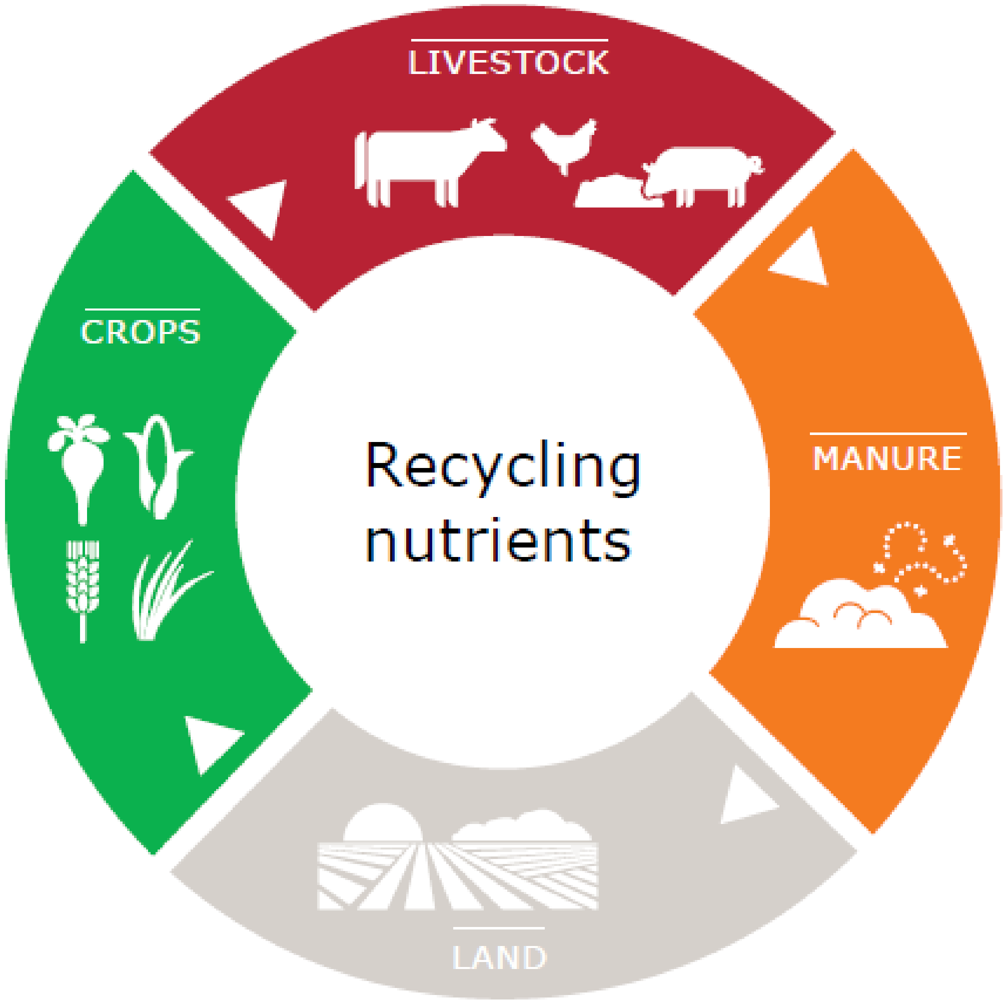
# Humanity has a massive challenge



# Circularity in agriculture

feed the world while preserving the environment by closing nutrient cycles (De Boer and Van Ittersum, 2018)

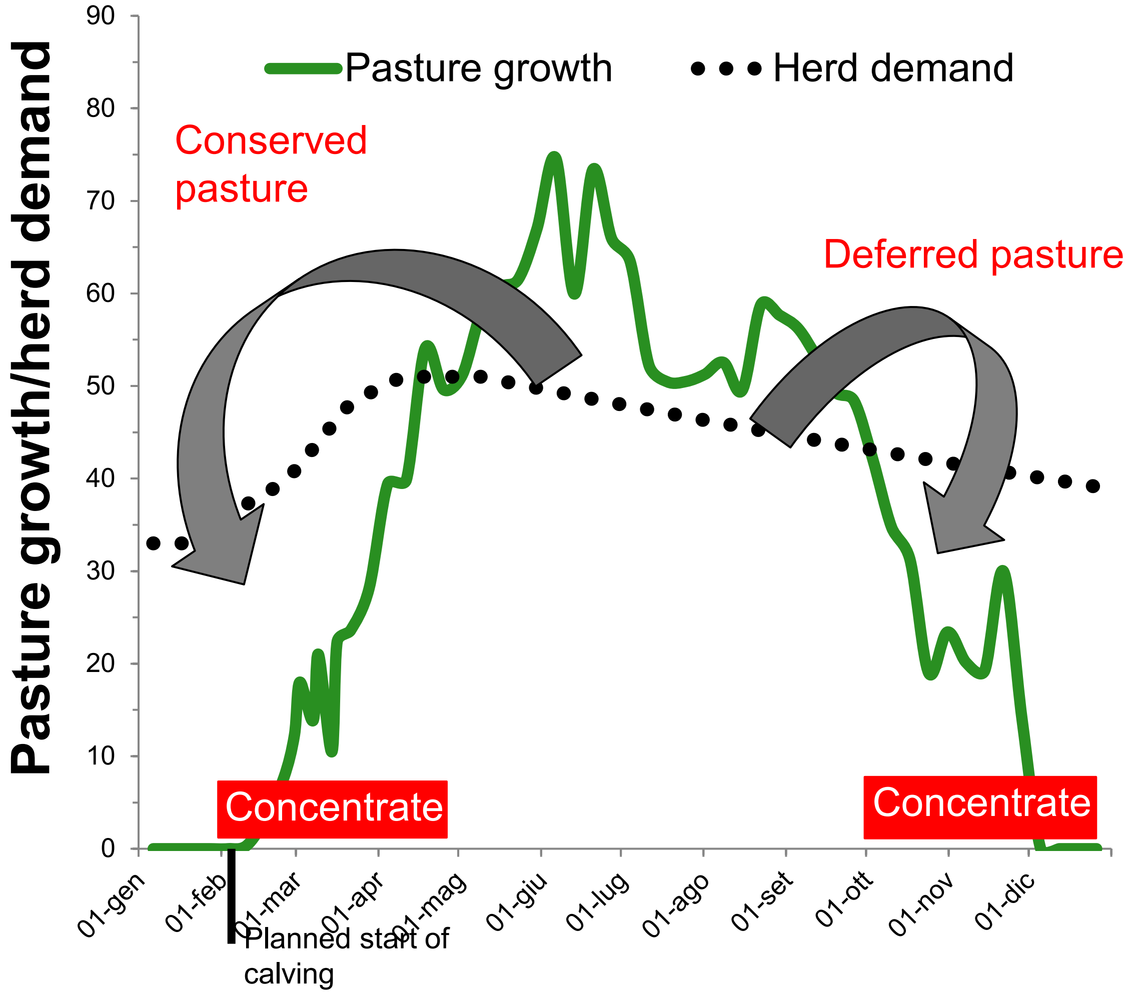
- Arable land feeds humans;
- Non-arable land (65-70% of world's agricultural land) feeds herbivores;
- Biomass unsuited to feed humans feeds animals (to feed humans);
- Biomass unsuited to feed animals fertilises the soil.




Source: Hoes et al. 2019. Towards sustainable food systems – a Dutch approach. Wageningen University & Research

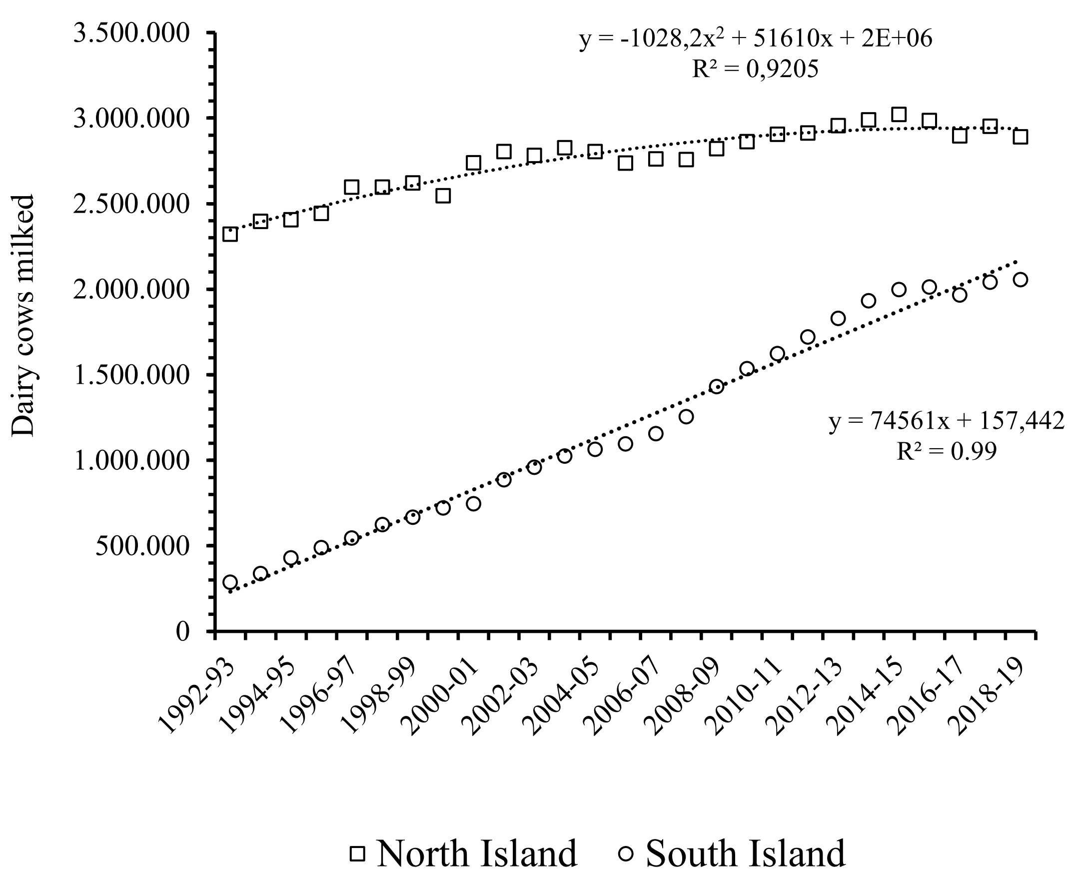
# Pasture-based systems

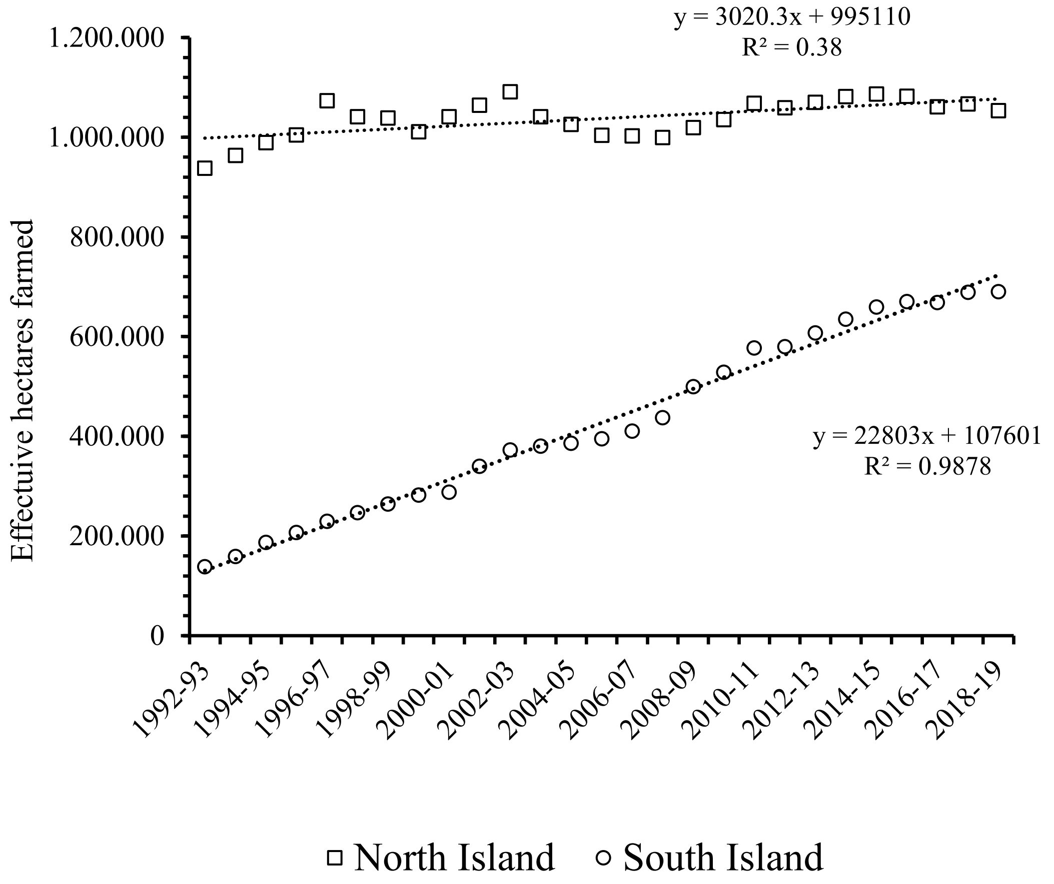
- Utilise feed indigestible to humans to produce high quality protein;
  - Requires Phosphorus, Potassium, Lime, as inputs;
  - Utilises land not suitable for crop;
  - Utilises waste biomass (co-products, silage/hay, root crops, in situ).
- Very close to Circular.



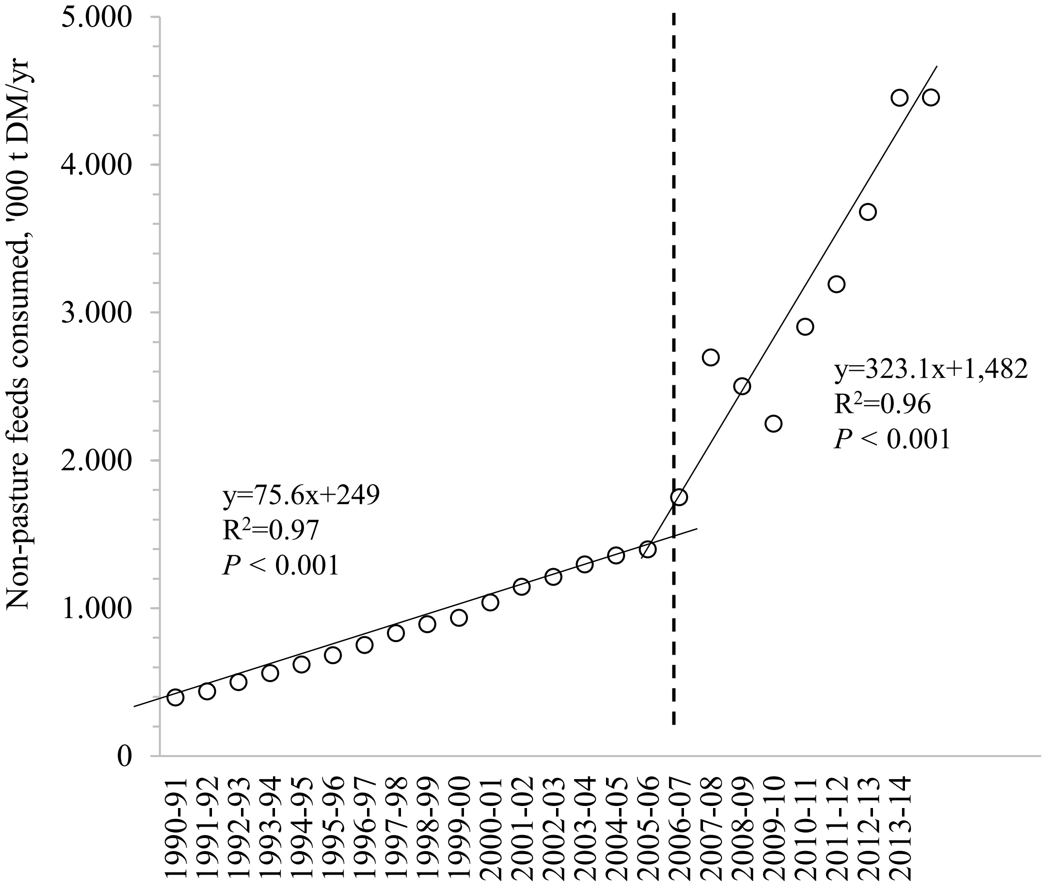

*Roche et al. 2017. Seasonal pasture-based dairy production systems. Large Dairy Herd Management, 3rd Ed. pp. 99-114.*

# 100% more cows on 70% more land



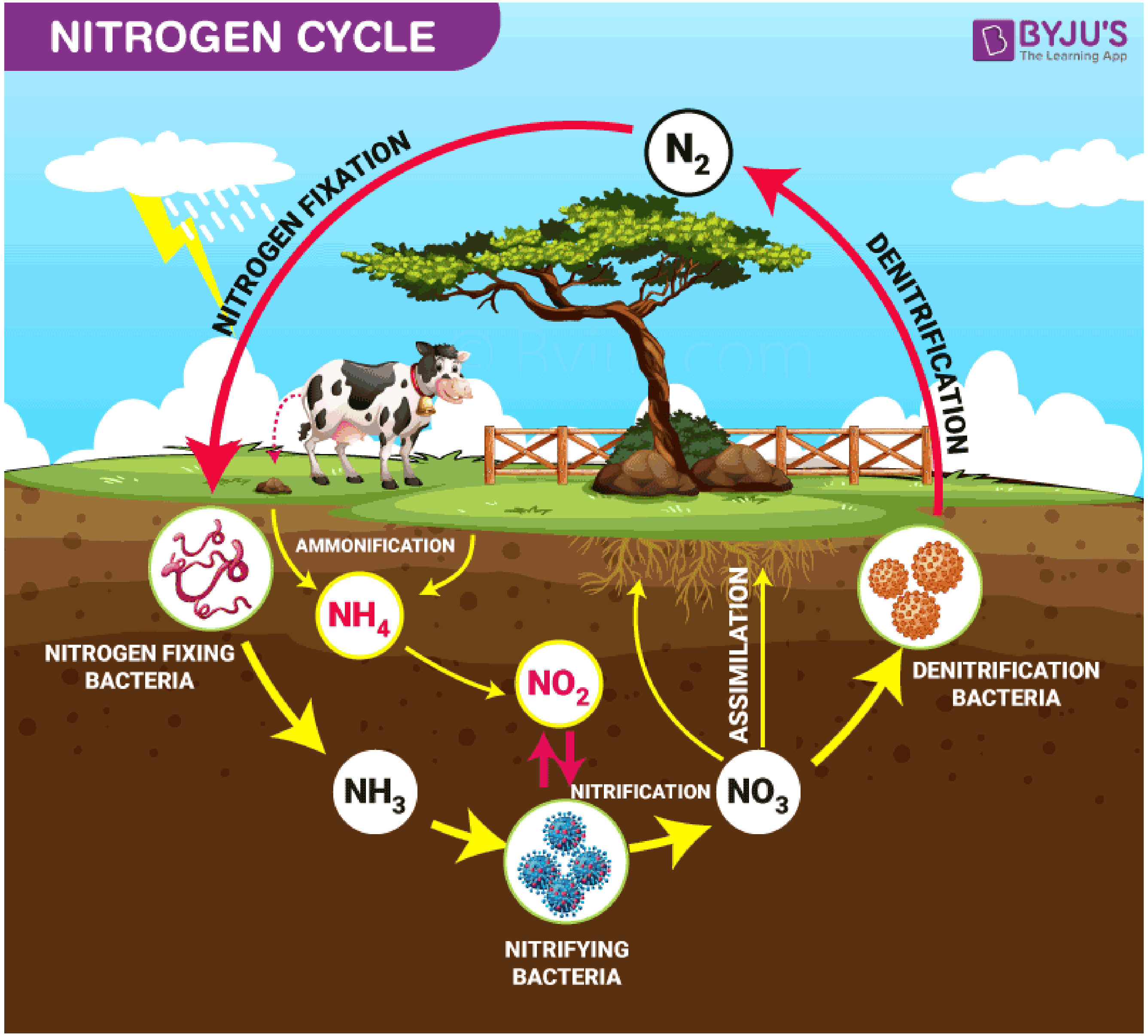



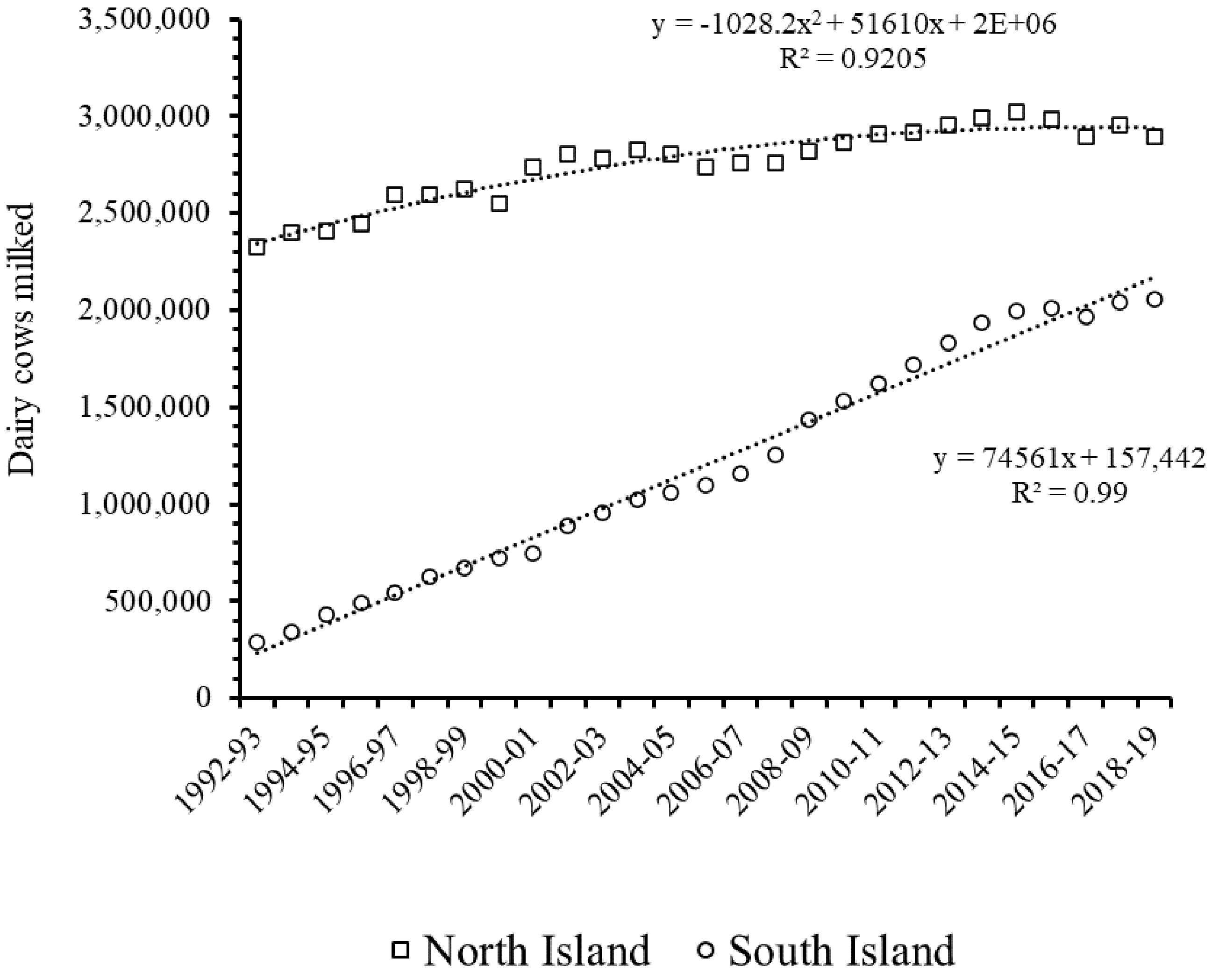
# Exponential increase in feed inputs nationally




# Nitrogen

- Est. ~50% of world's food is from N from fertilizer;
- No shortage of nitrogen;
  - 78% of atmosphere.
- High energy demand for atm nitrogen fixation;
  - Managing C footprint
- Loss of nitrogen from productive systems;
  - Managing river, lake and estuarine water quality






Hydrol. Earth Syst. Sci., 21, 1149–1171, 2017
www.hydrol-earth-syst-sci.net/21/1149/2017/
doi:10.5194/hess-21-1149-2017


Hydrology and Earth System Sciences

**River water quality changes in New Zealand over 26 years: response to land use intensity**

**Jason P. Julian[1,5], Kirsten M. de Beurs[2,5], Braden Owsley[2,5], Robert J. Davies-Colley[3], and Anne-Gaelle E. Ausseil[4]**

[1]Department of Geography, Texas State University, San Marcos, TX, USA
[2]Department of Geography and Environmental Sustainability, The University of Oklahoma, Norman, OK, USA
[3]National Institute of Water and Atmospheric Research (NIWA), Hamilton, New Zealand
[4]Landcare Research, Palmerston North, New Zealand
[5]Landscape & Land Use Change Institute (LLUCI), University of Oklahoma and Texas State University, Oklahoma, Texas, USA

## Water quality – 1990-2015

- Total N ↑ 42%
- Oxidised N ↑ 35%
- Conductivity ↑ 67%

- Primarily lowland waterways;
- Intensively managed grassland;
- $R^2$ = 62% with dairy cattle.

J. Dairy Sci. 99:5916–5925
http://dx.doi.org/10.3168/jds.2016-11024


# Increased stocking rate and associated strategic dry-off decision rules reduced the amount of nitrate-N leached under grazing

J. R. Roche,*[1] S. F. Ledgard,† M. S. Sprosen,† S. B. Lindsey,† J. W. Penno,*[2] B. Horan,‡ and K. A. Macdonald*
*DairyNZ, Private Bag 3221, Hamilton 3240, New Zealand
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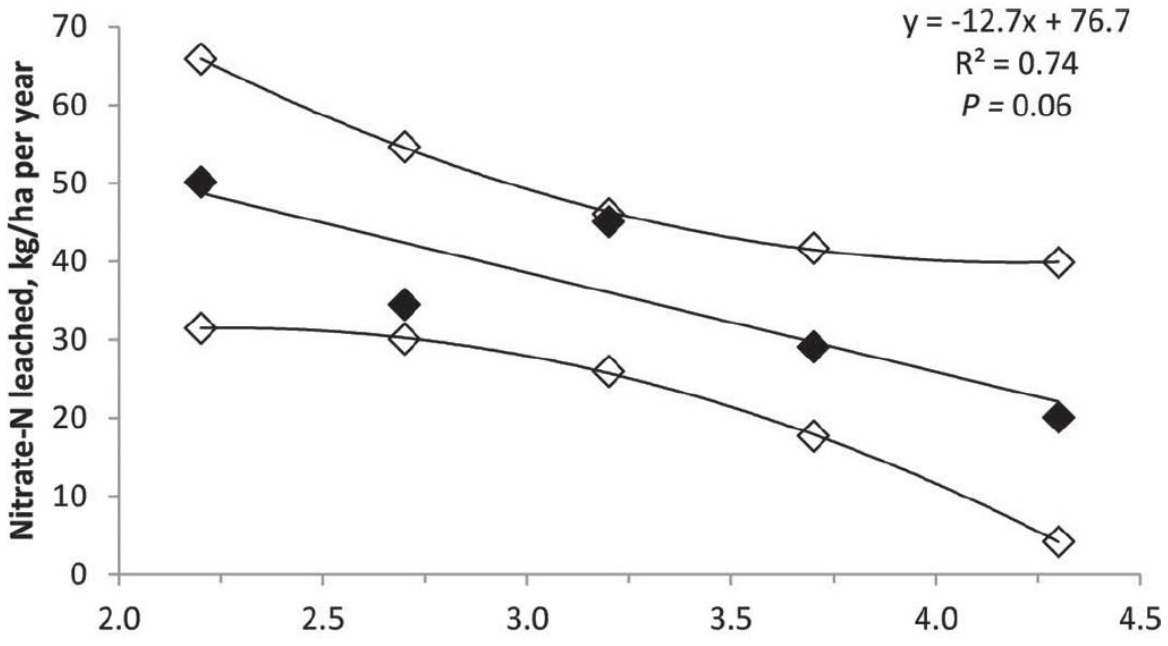
‡Teagasc Moorepark, Fermoy, Co. Cork, Ireland P61 P302



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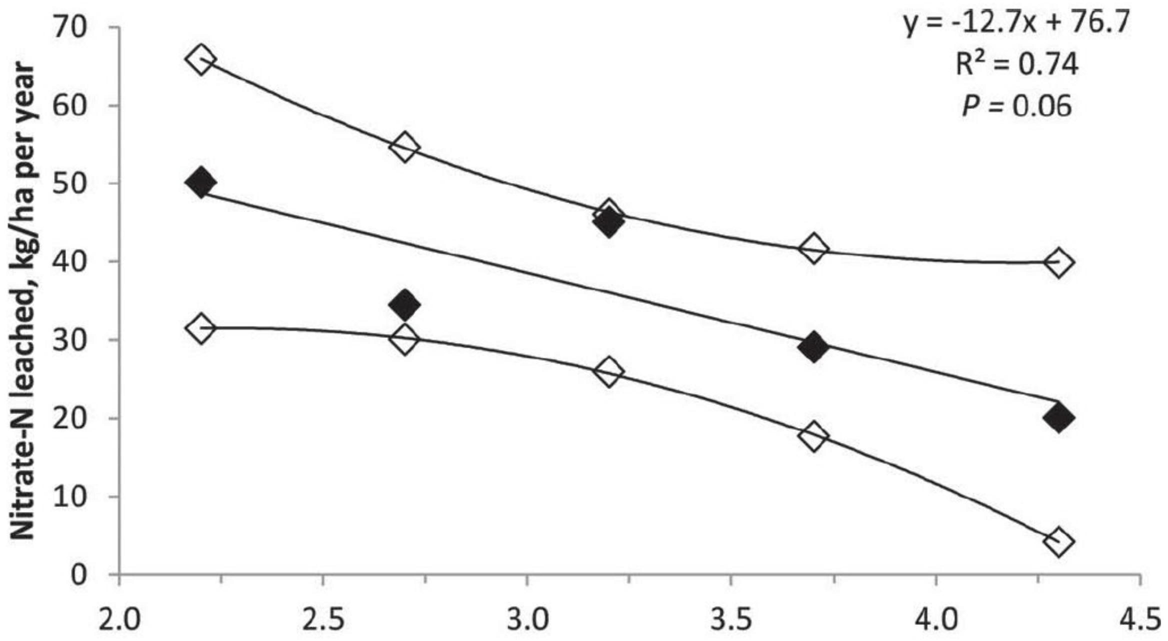
## NITROGEN LEACHING AS AFFECTED BY DAIRY INTENSIFICATION AND MITIGATION PRACTICES IN THE RESOURCE EFFICIENT DAIRYING (RED) TRIAL

Stewart Ledgard[1], Mike Sprosen[1], Amanda Judge[1], Stuart Lindsey[1], Rodger Jensen[2], Dave Clark[2] and Jiafa Luo[1]

[1]*AgResearch Ruakura Research Centre, Hamilton, New Zealand*
[2] *Dexcel, Hamilton, New Zealand*



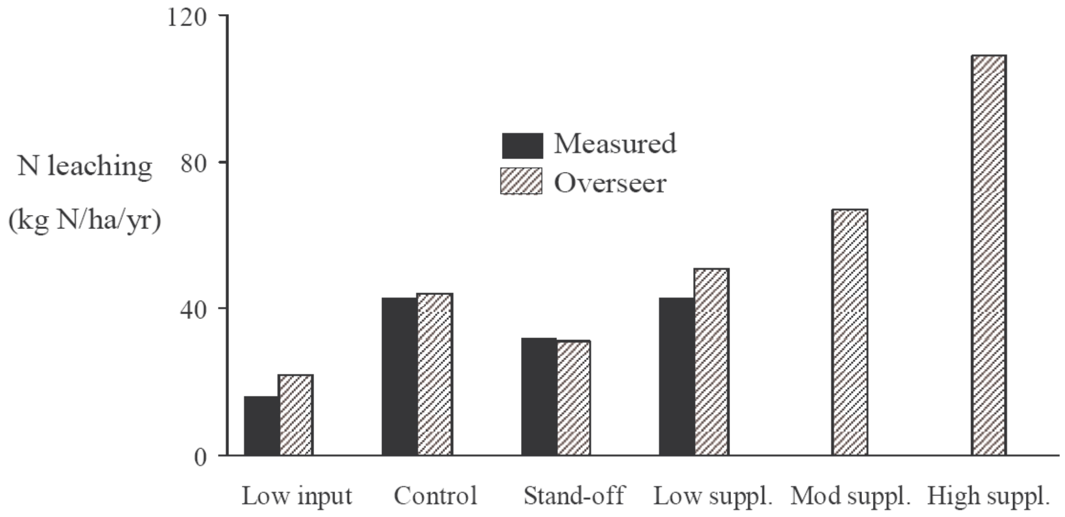
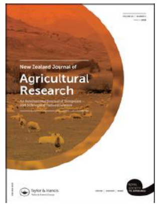




**Figure 2.** Average annual N leaching (measured and predicted using overseer model) from dairy farmlets.

# Mitigations

**Recognising that most N loss is via urine patch during sensitive months.**

- N fertilizer limited to 190kg/ha;
- Reducing N surplus in diet during sensitive months;
- Low N supplements and crops;
- Variable rate irrigation;
- Constructed wetlands in flow pathways;



New Zealand Journal of Agricultural Research

Taylor & Francis

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Quantifying contaminant losses to water from pastoral land uses in New Zealand III. What could be achieved by 2035?

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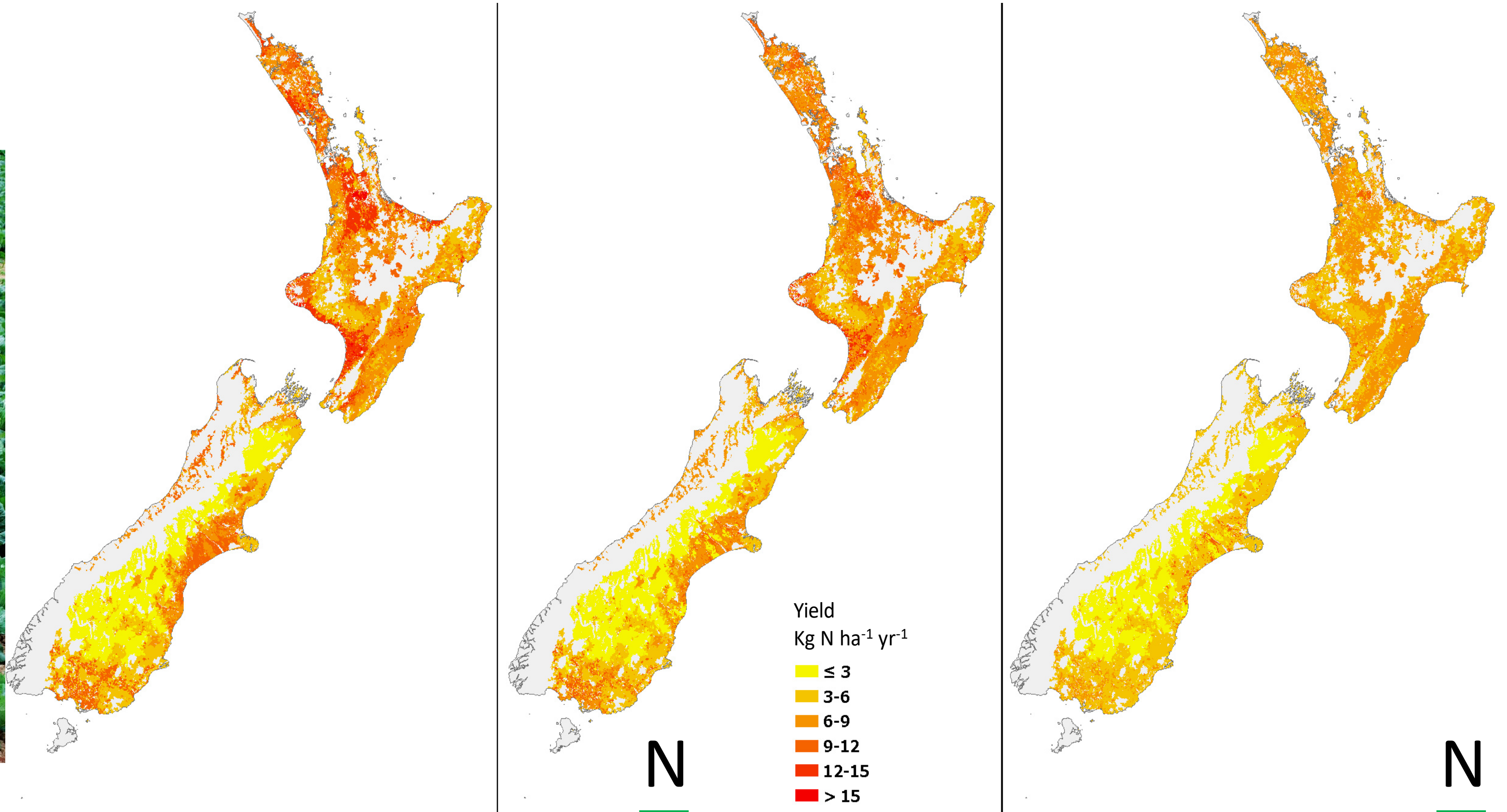
# What could we achieve by 2035?

Current | Established measures | Established + developing

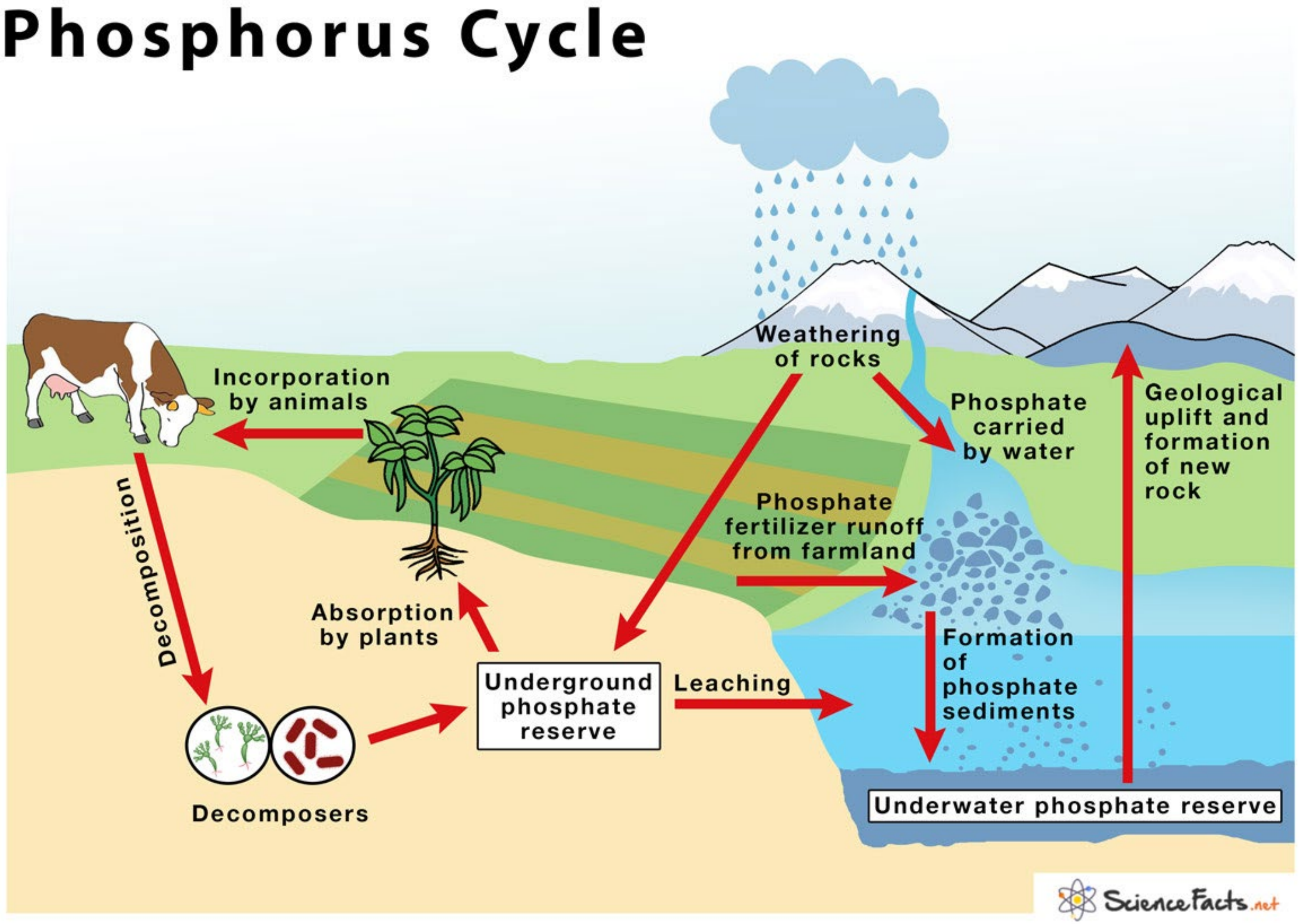



N 19% ↓

N 34% ↓

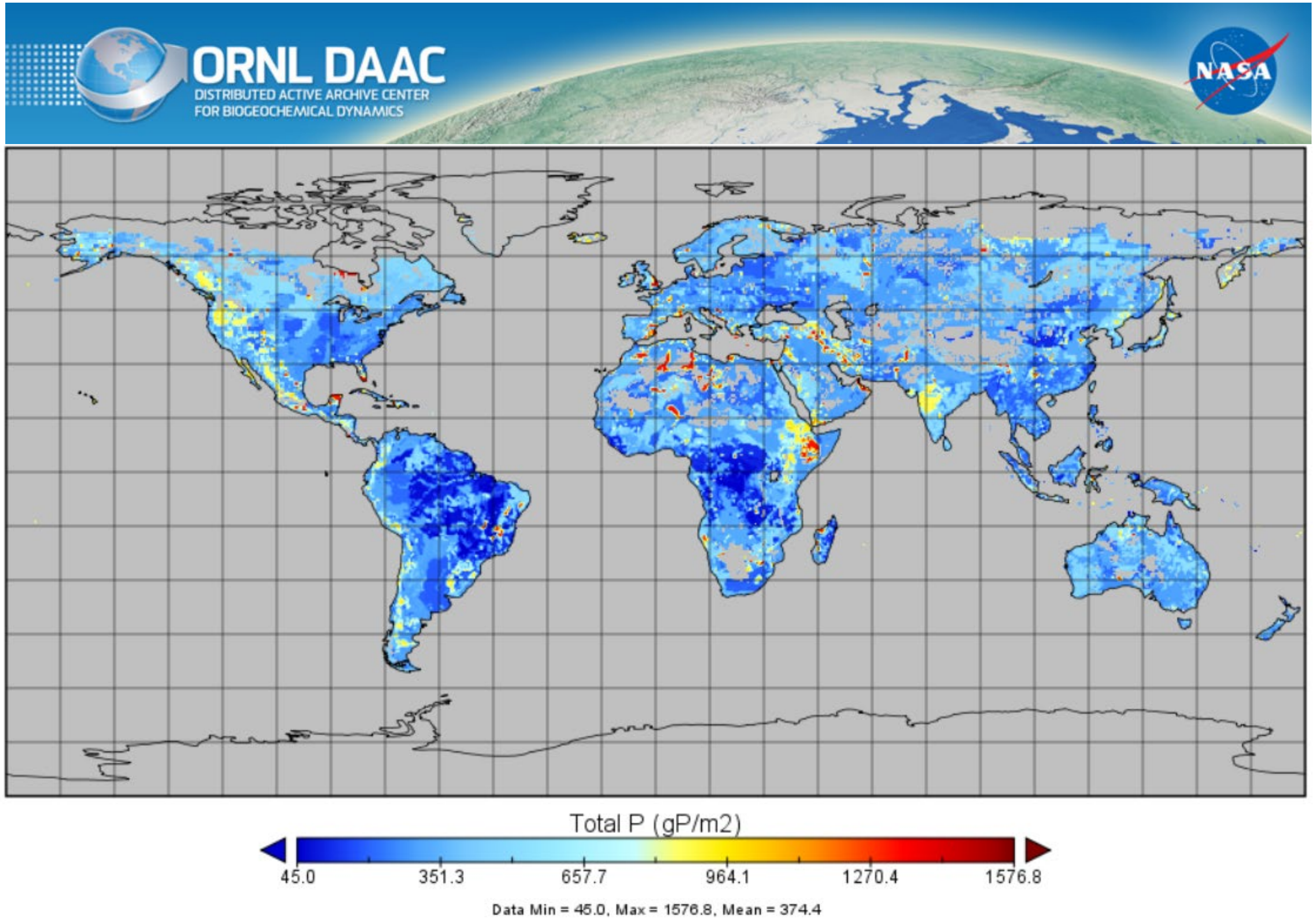
# Phosphorus

- Essential element for biological systems;
- Cannot be created or destroyed;
- Geographical availability;
  - ~70-80% in Western Sahara.
- Limited availability – but essential (concern about peak P);
- Loss of phosphorus from productive systems;
  - Managing river, lake and estuarine water quality



# Phosphorus sources

- Limited phosphorus stores
  - ~300-500 billion tonnes
- Geographically isolated
  - NW Africa (70%)
  - Middle East
  - Mexico



nature food

Analysis

https://doi.org/10.1038/s43016-024-00952-9

# Phosphorus applications adjusted to optimal crop yields can help sustain global phosphorus reserves

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Accepted: 29 February 2024

Published online: 25 March 2024

Check for updates

R. W. McDowell[1,2], P. Pletnyakov[2] & P. M. Haygarth[3]

With the longevity of phosphorus reserves uncertain, distributing phosphorus to meet food production needs is a global challenge. Here we match plant-available soil Olsen phosphorus concentrations to thresholds for optimal productivity of improved grassland and 28 of the world's most widely grown and valuable crops. We find more land (73%) below optimal production thresholds than above. We calculate that an initial capital application of 56,954 kt could boost soil Olsen phosphorus to their threshold concentrations and that 28,067 kt $yr^{-1}$ (17,500 kt $yr^{-1}$ to cropland) could maintain these thresholds. Without additional reserves becoming available, it would take 454 years at the current rate of application (20,500 kt $yr^{-1}$) to exhaust estimated reserves (2020 value), compared with 531 years at our estimated maintenance rate and 469 years if phosphorus deficits were alleviated. More judicious use of phosphorus fertilizers to account for soil Olsen phosphorus can help achieve optimal production without accelerating the depletion of phosphorus reserves.

Human existence over the past century has depended on the production of phosphorus fertilizer and its application to agricultural soils to drive food production[1]. Phosphorus fertilizer production relies on geologic rock phosphorus supplies extracted from mines at relatively few locations and requires transportation and distribution before application to farmlands worldwide. The global population is projected to increase to nearly 10 billion people by 2050[2]. It has been projected that feeding this increased population will require an additional 500 million hectares of arable land unless phosphorus can be more efficiently used to boost or maintain optimal crop yields[3]. Most of this efficiency will be created by local management solutions that apply phosphorus fertilizers only where they are needed and by making better use of available soil phosphorus concentrations[4].

To boost crop yields, we must close the gap between actual and potential yields with more judicious application of fertilizer to match available soil phosphorus concentrations and crop demands[5]. Global estimates put the overapplication of phosphorus fertilizers at 30–40% relative to crop and grassland requirements[5–7]. Some of this can be redistributed, but the efficiency gain may still not meet crop and food demands[8]. Redistribution and the lowering of soil phosphorus concentrations, especially in some jurisdictions such as China and Europe, will also help avoid the risk of surface water quality deterioration[9]. However, the spatial distribution of soil phosphorus concentrations is uncertain. Previous work has modelled the spatial distribution of available soil phosphorus concentrations and stocks in Africa and Europe[10,11]. Estimates of concentrations and stocks have also been made at a global level, but these are of total phosphorus, not plant-available phosphorus in agricultural soils[12,13]. Additional estimates of phosphorus flows have been derived by mass balance models that consider factors such as plant uptake, weathering and global lithology data[3,14–17], but again these do not estimate plant-available phosphorus.

Accurate knowledge of where crops are grown and the available soil phosphorus concentration of those soils is a key step in reducing yield gaps and making optimal use of phosphorus fertilizer reserves. Recent work has updated and improved the spatial resolution of the major crops, rangeland, improved grassland

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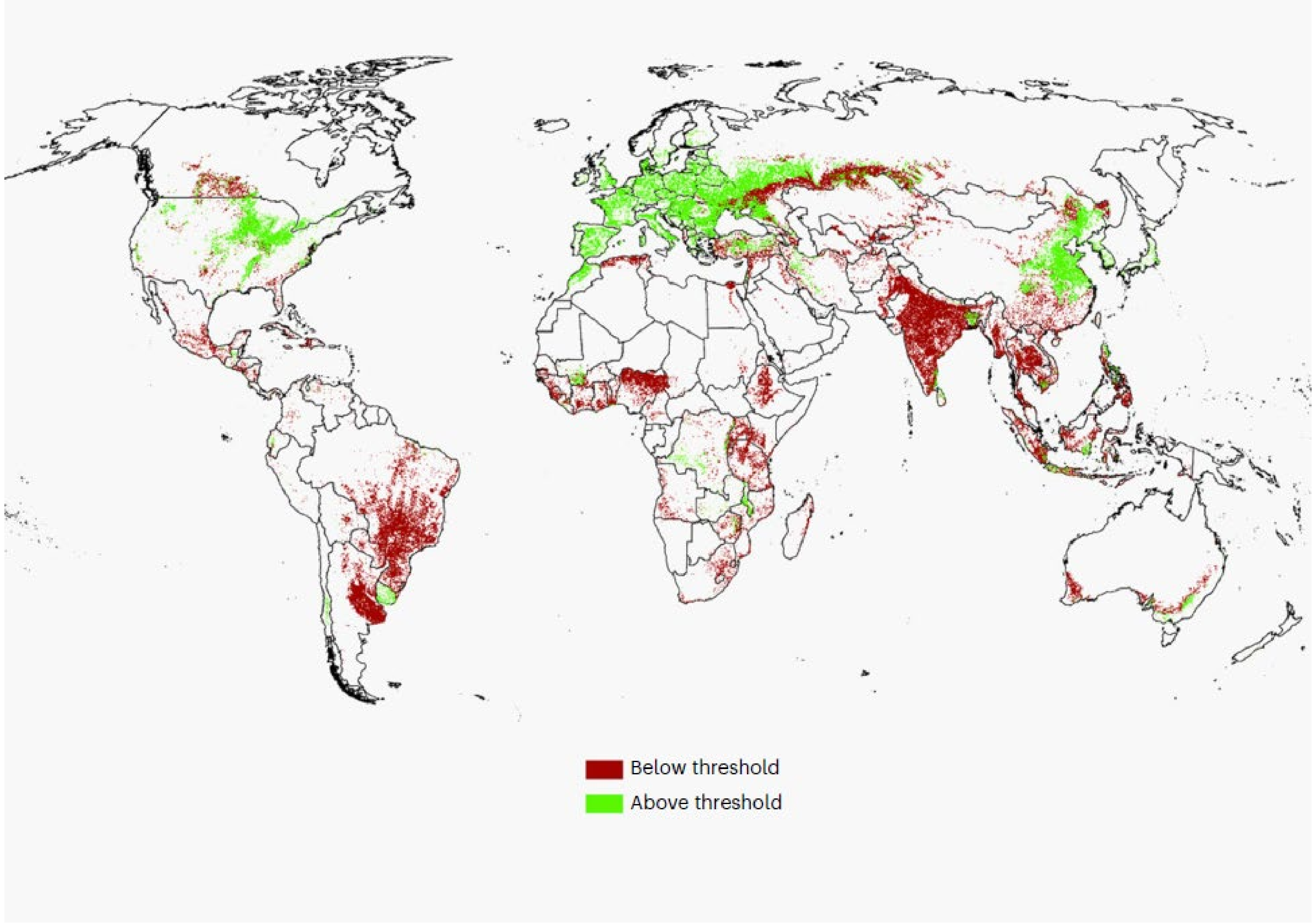



**Figure 1. The global distribution of land area planted with rice, soybeans, maize, wheat, rye, barley, oranges or apples above or below their agronomic threshold of 15 mg kg−1 required for optimum production**

scientific data

OPEN

DATA DESCRIPTOR

# A Global Database of Soil Plant Available Phosphorus

R. W. McDowell[1,2] ✉, A. Noble[1], P. Pletnyakov[1] & P. M. Haygarth[3]

Soil phosphorus drives food production that is needed to feed a growing global population. However, knowledge of plant available phosphorus stocks at a global scale is poor but needed to better match phosphorus fertiliser supply to crop demand. We collated, checked, converted, and filtered a database of *c.* 575,000 soil samples to *c.* 33,000 soil samples of soil Olsen phosphorus concentrations. These data represent the most up-to-date repository of freely available data for plant available phosphorus at a global scale. We used these data to derive a model ($R^2 = 0.54$) of topsoil Olsen phosphorus concentrations that when combined with data on bulk density predicted the distribution and global stock of soil Olsen phosphorus. We expect that these data can be used to not only show where plant available P should be boosted, but also where it can be drawn down to make more efficient use of fertiliser phosphorus and to minimise likely phosphorus loss and degradation of water quality.

## Background & Summary

Soil phosphorus drives food production required to feed an increasing global population that is projected to reach 10 billion people by 2050[1]. It has been estimated that an additional 500 million hectares of arable land will be required to feed this increased population unless phosphorus can be either better utilised by plants or applied more efficiently[2]. Much of this efficiency will arise from local management solutions that only apply phosphorus fertilisers where they are needed[3]. However, knowledge of plant-available soil phosphorus stocks is poor, globally.

Some estimates have been made of global soil total phosphorus but only considers soils in their natural state, that is without the addition of fertilisers[4,5]. Similarly, regional estimates exist of plant available soil phosphorus stocks using measured data[6–8]. However, global estimates of plant available soil phosphorus stocks using measured data do not exist. Instead, global stocks have been estimated using models of factors such as plant uptake, weathering and global lithology data[9–12] or via mass balance approaches[2,13]. It is important to know where available soil phosphorus concentrations are adequate or deficient for optimal crop growth. This knowledge enables us to better match phosphorus fertiliser supply to crop demand and to suggest where excess plant available soil phosphorus can be drawn down[11,14]. Here we present the first global database of freely available data on plant available soil phosphorus concentrations and use these data to create a global map and calculate the global stocks of plant available soil phosphorus stocks. We chose bicarbonate-extractable Olsen phosphorus[15] as the measure of plant available soil phosphorus as it is the most widely used form, globally.

## Methods

**Data filtering and evaluation.** Data (n = 574,375) of available soil phosphorus were obtained from 19 regional or global databases and published studies. These were chosen for their geographic spread and representativeness of a mix of developed and developing nations and where there was a clear process in place to ensure that data were of good quality (Table 1). Prior to modelling the data to estimate global Olsen phosphorus stocks, we adopted a multi-step process (Fig. 1) to produce a globally consistent dataset. The steps comprised (1) inspecting the data and filtering it for consistent analytical methods, units, and a limit of detection (set as 2 mg $kg^{-1}$); (2) filtering data to remove points lacking correct geo-referencing and those falling outside an acceptable time span (from 2000–2019); (3) converting values into Olsen phosphorus concentrations via established equations (Table 2), if necessary; and 4) filtering data to remove points from depths > 20 cm and eliminating any duplicate values.

*Step 1 Inspect data.* When examining data, we determined that the soil extraction method was recorded, and that the phosphorus extraction relied on acceptable procedures. Measurements of phosphorus based on molybdenum blue colorimetry or ion chromatography were considered comparable and acceptable. Measurements

[1]AgResearch, Lincoln Science Centre, Private Bag 4749, Christchurch, 8140, New Zealand. [2]Faculty of Agriculture and Life Sciences, Lincoln University, Lincoln, P O Box 84, 7647, Christchurch, New Zealand. [3]Lancaster Environment Centre, Lancaster University, Lancaster, LA1 4YQ, UK. ✉e-mail: richard.mcdowell@agresearch.co.nz





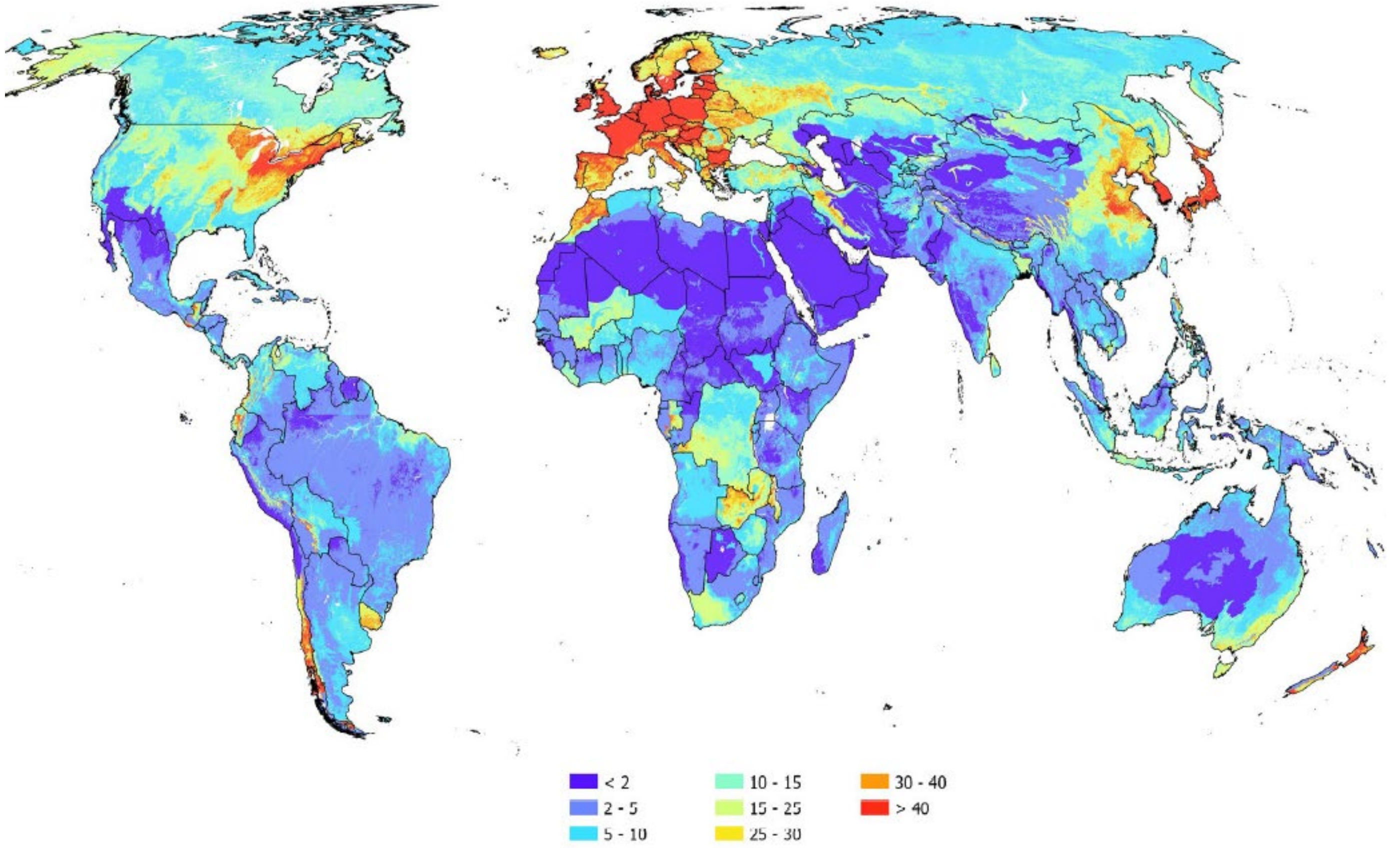
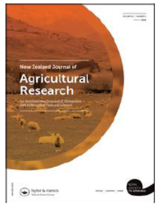



**Fig. 3** Global topsoil Olsen phosphorus concentration (mg kg−1).

# Mitigations

**Recognising that P lost primarily through overland flow pathways.**

- Fencing watercourses with setback;
- Riparian zones around waterbodies;
- Detention bunds in flow pathways;
- Constructed wetlands in flow pathways;



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# What could we achieve by 2035?

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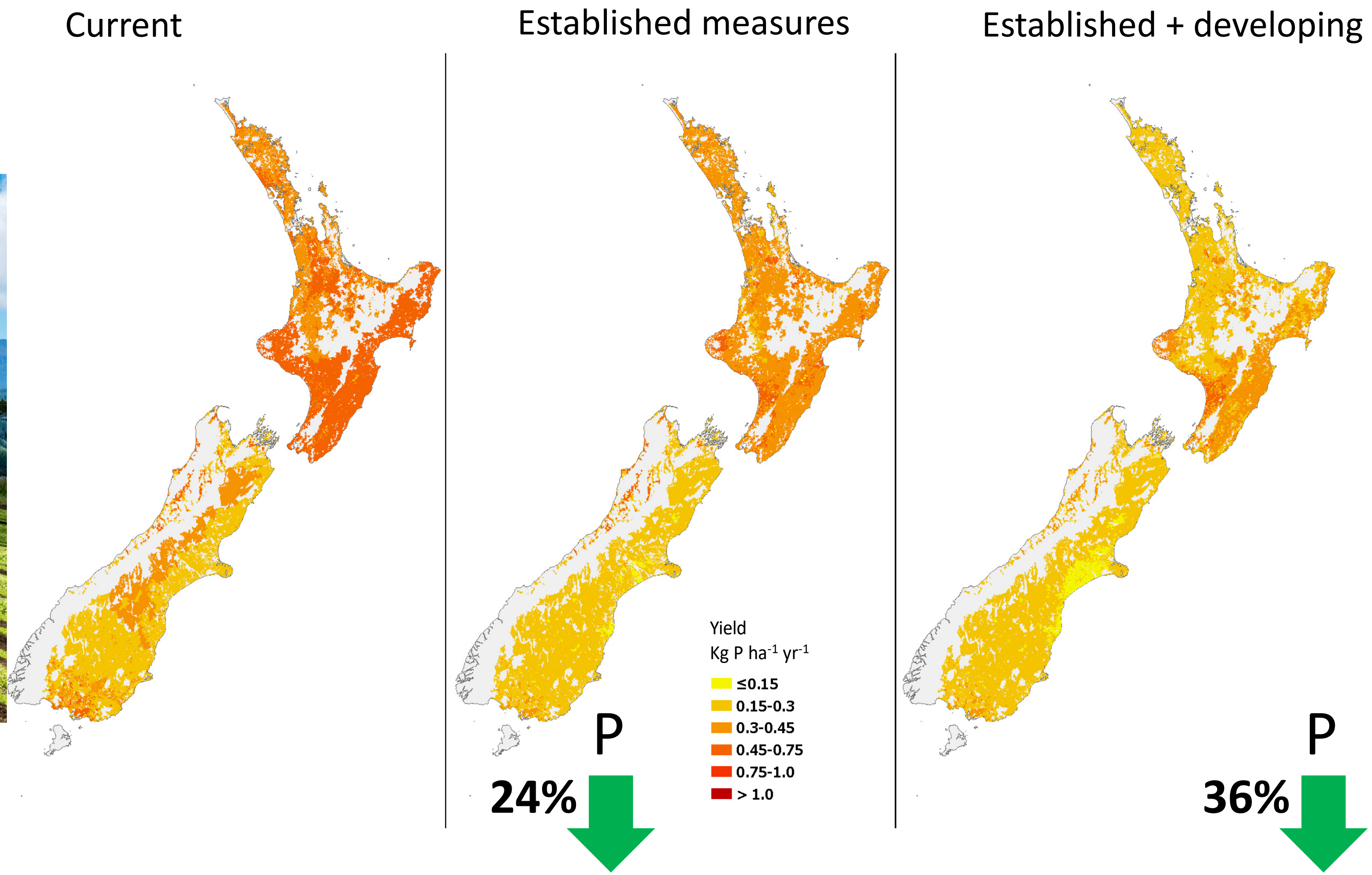
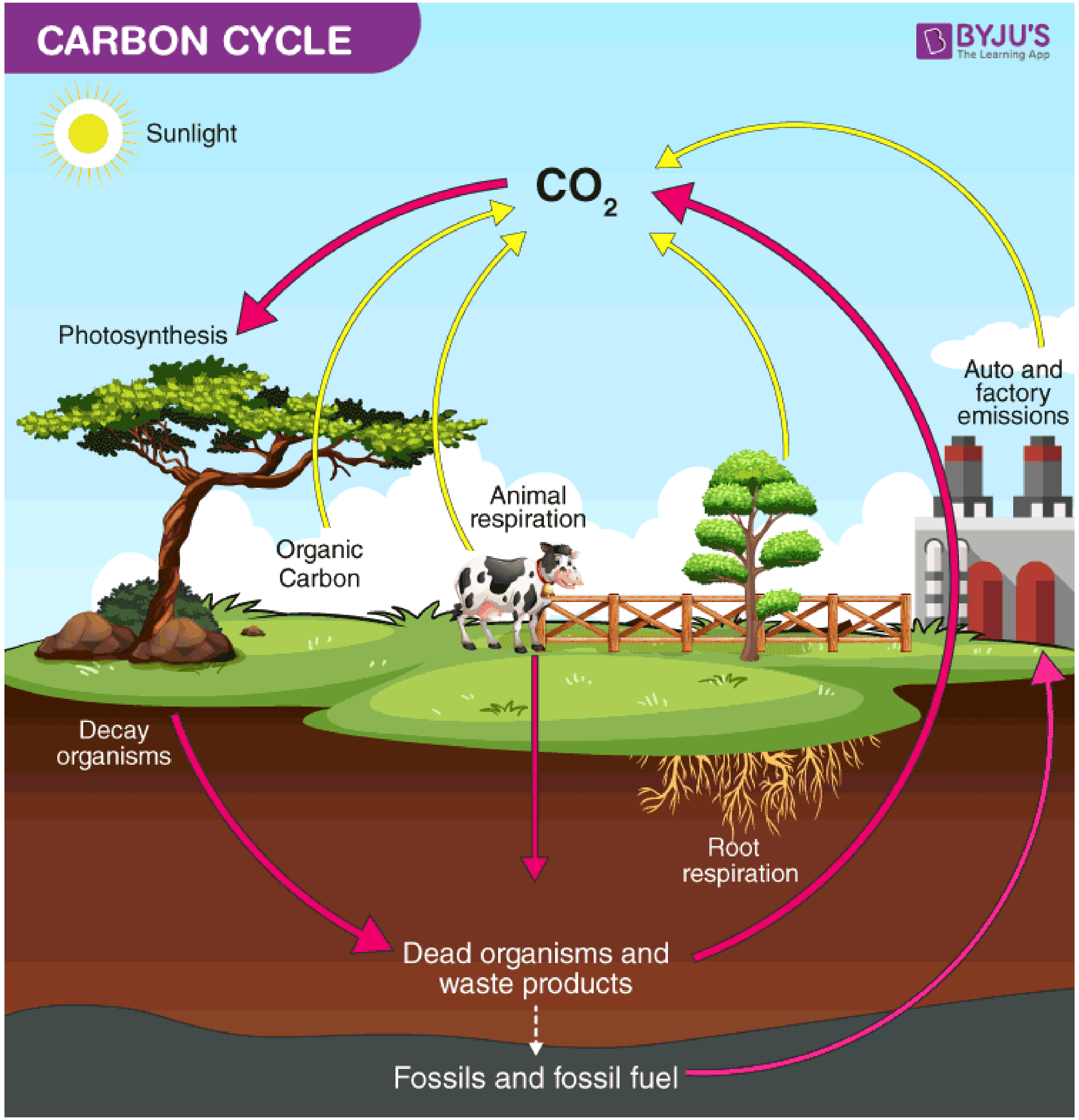


# Carbon

- C is constantly recycled between the atmosphere, plants, and animals;
- No shortage of C;
  - Problem is increasing atmospheric concentrations;
  - Ruminant animals produce methane (strong forcing effect);

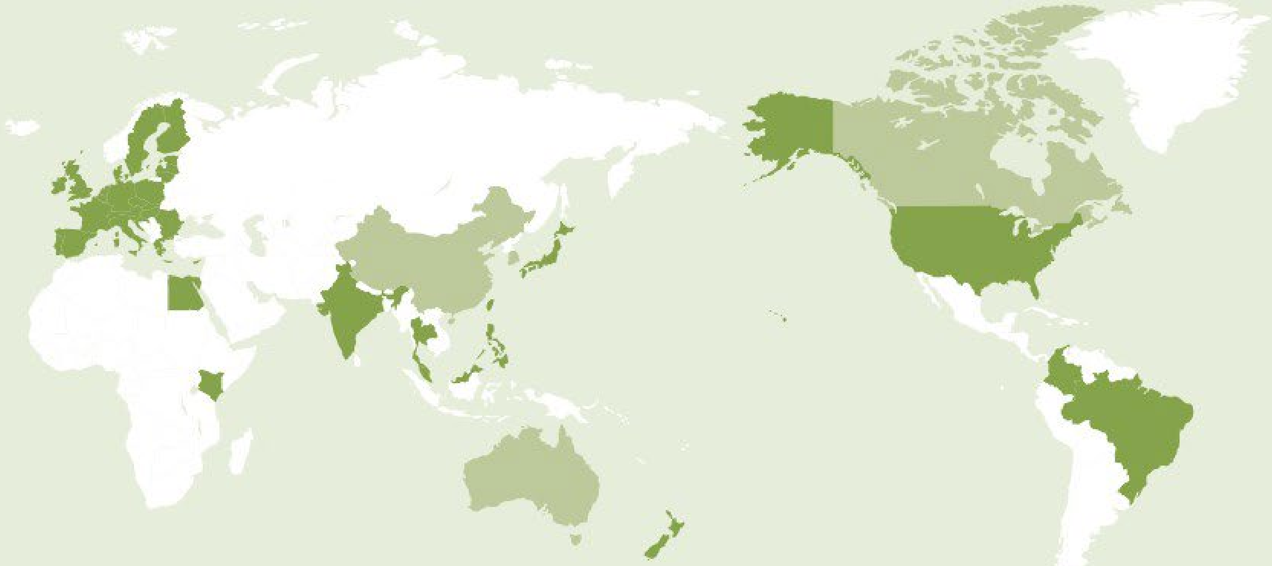


# Sustainability reporting an ongoing feature of trade requirements

## At a glance: international climate & sustainability disclosure requirements

**KEY:**

- Mandatory CRD in force
- Mandatory CRD proposed



### SECTION OVERVIEW

The global regulatory landscape with respect to ESG reporting is changing at pace. More than 60% of world GDP is now subject to mandatory climate-related disclosures (CRD) measures, either proposed or already in force. This page provides an at-a-glance overview of measures in key markets. These obligations could affect New Zealand companies directly, depending on in-market presence, or indirectly through the supply chain requirements of their customers in those countries. In addition, there is widespread uptake of voluntary reporting under initiatives such as the Task Force on Nature-related Financial Disclosures (TNFD).

**UK & EUROPE**

**United Kingdom**
- Mandatory CRD (since 2022)
- Emissions reporting requirements
- Sustainability Disclosure Requirements (since 2023)
- Modern slavery reporting (since 2015)

**European Union**
- Corporate Sustainability Reporting Directive (from 2026)
- Corporate Sustainability Due Diligence Directive (likely from 2026)

**ASIA PACIFIC**

**India**
- Listed issuer ESG disclosures (phased in from 2022)

**China**
- Listed issuer ESG disclosures (from 2024)
- Emissions reporting requirements (various requirements since 2006)

**Taiwan**
- Emissions reporting requirements (since 2021)
- Listed issuer ESG disclosures (since 2023)

**Hong Kong**
- Listed issuer ESG disclosures (since 2023)
- CRD (from 2025)

**Korea**
- Emissions reporting (amended 2021)
- ESG disclosures (proposed from 2026)
- Human rights in supply chain reporting (from 2024)

**Japan**
- Emissions reporting (since 2021)
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- Sustainability disclosures (proposed from 2025)

**Singapore**
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- Listed issuer ESG disclosures (since 2023)
- CRD (from 2025)

**Thailand**
- Listed issuer ESG disclosures (since 2021)
- Emissions reporting (proposed 2024)

**Vietnam**
- Listed issuer ESG disclosures (since 2020)
- Emissions reporting (since 2022)

**Malaysia**
- Listed issuer ESG disclosures (since 2023)
- Enhanced CRD and sustainability disclosures (proposed from 2025)

**Indonesia**
- Listed issuer ESG disclosures (since 2022)
- Environmental and ESG planning (since 2012)

**Philippines**
- Listed issuer ESG disclosures (from 2025)

**AUSTRALIA**
- CRD (proposed from 2025)
- Modern slavery reporting (since 2018)
- Emissions reporting requirements (since 2007)

**NORTH AMERICA**

**United States**
- CRD (rule finalised in 2024; currently on hold)
- California Climate Accountability Package, including emissions reporting, CRD and carbon offset disclosures (from 2026)
- New York (proposed) and California (since 2010) supply chain due diligence requirements

**Canada**
- CRD for financial institutions (from 2024)
- Sustainability disclosures (from 2025)
- Human rights supply chain reporting (from 2024)

*Source: Chapman Tripp Report for The Aotearoa Circle – April 2024*

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- Listed issuer ESG disclosures (since 2023)

**Hong Kong**
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- CRD (from 2025)

**Korea**
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- ESG disclosures (proposed from 2026)
- Human rights in supply chain reporting (from 2024)

**Japan**
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- Listed issuer ESG disclosures (since 2022)
- Environmental and ESG planning (since 2012)

**Philippines**
- Listed issuer ESG disclosures (from 2025)

**AUSTRALIA**
- CRD (proposed from 2025)
- Modern slavery reporting (since 2018)
- Emissions reporting requirements (since 2007)

**NORTH AMERICA**

**United States**
- CRD (rule finalised in 2024; currently on hold)
- California Climate Accountability Package, including emissions reporting, CRD and carbon offset disclosures (from 2026)
- New York (proposed) and California (since 2010) supply chain due diligence requirements

**Canada**
- CRD for financial institutions (from 2024)
- Sustainability disclosures (from 2025)
- Human rights supply chain reporting (from 2024)

*Source: Chapman Tripp Report for The Aotearoa Circle – April 2024*

# Corporate Pledges to meet warming neutrality

Nestlé

20% emissions reduction by 2025, 50% by 2030, and
Net Zero emissions by 2040 [at the latest]

JBS FOODS

net-zero greenhouse gas emissions by 2040

DANONE ONE PLANET. ONE HEALTH

reduce absolute methane emissions from its fresh milk supply chain by 30% by 2030

Cargill

reduce supply chain emissions by 30% by 2030

KraftHeinz

emissions reduction of 50% by 2030 across all Scope 1, 2 & 3

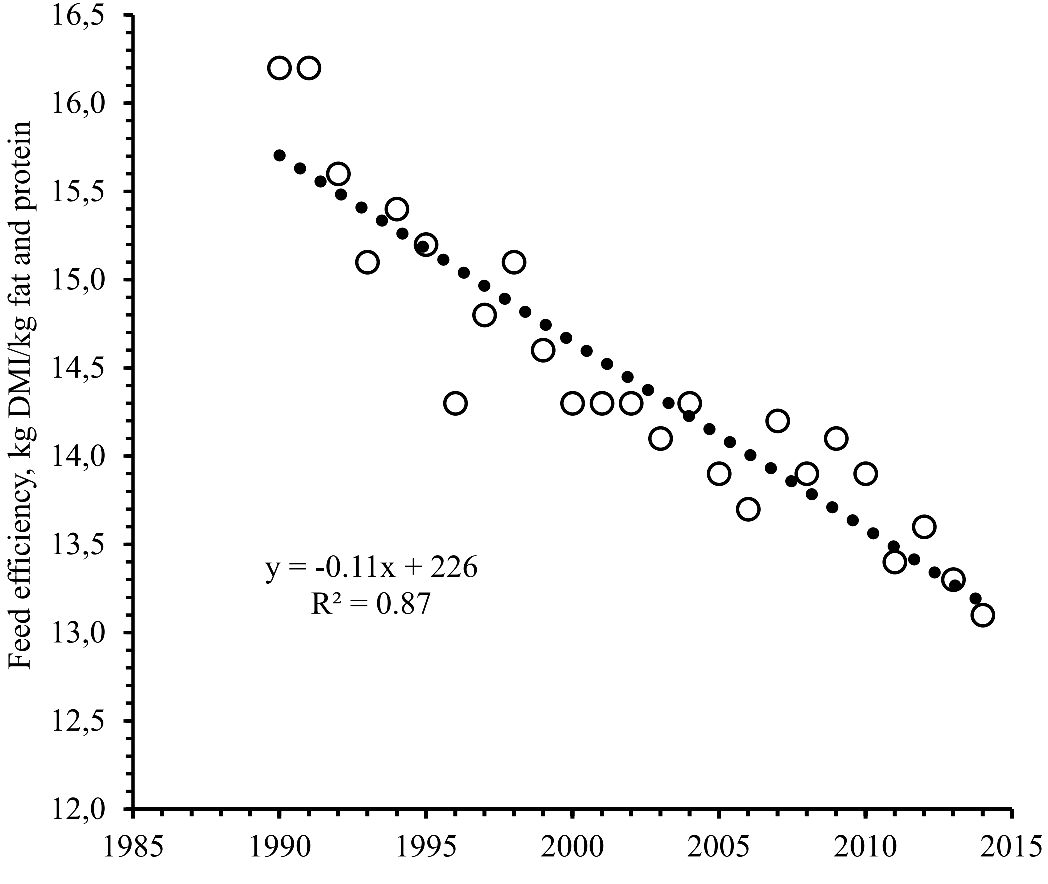
net zero greenhouse gas ("GHG") emissions across its operational footprint (Scope 1 and Scope 2) and entire global supply chain (Scope 3) by 2050

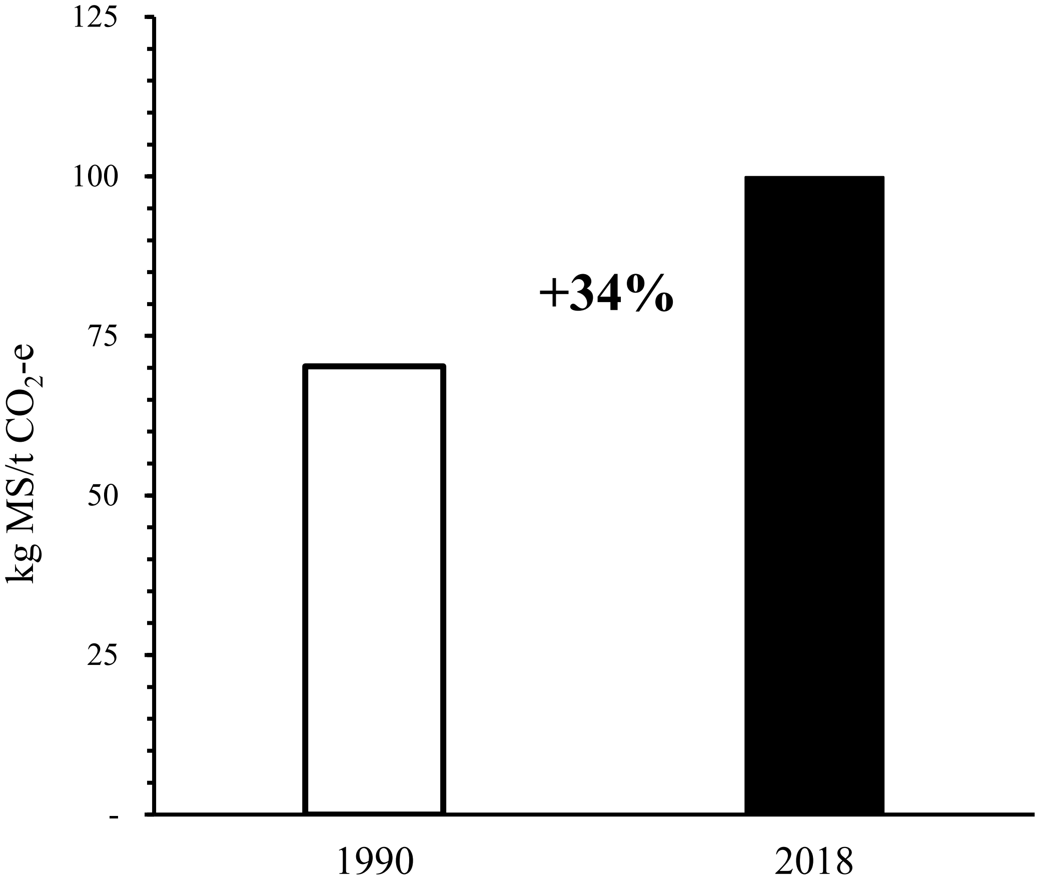
# Mitigations

**Enteric fermentation is >95% of methane and >80% GHG on a grazing farm**

- Genetics for efficiency and low methane;

# Increased efficiency – more milk/kg DMI or $CO_2$-e






Ministry for Primary Industries
Manatū Ahu Matua

# Mitigations

**Enteric fermentation is >95% of methane and >80% GHG on a grazing farm**

- Genetics for efficiency and low methane;
- Rumen modifiers;
- Methane inhibitors;
- Effluent pond inhibitor;
- Vaccine.

J. Dairy Sci. 105:9713–9725
https://doi.org/10.3168/jds.2022-22117


# Mapping the carbon footprint of milk production from cattle: A systematic review

**Andre M. Mazzetto,[1*] Shelley Falconer,[2] and Stewart Ledgard[2]**
[1]AgResearch Limited, Lincoln Research Centre, Lincoln 7674, New Zealand
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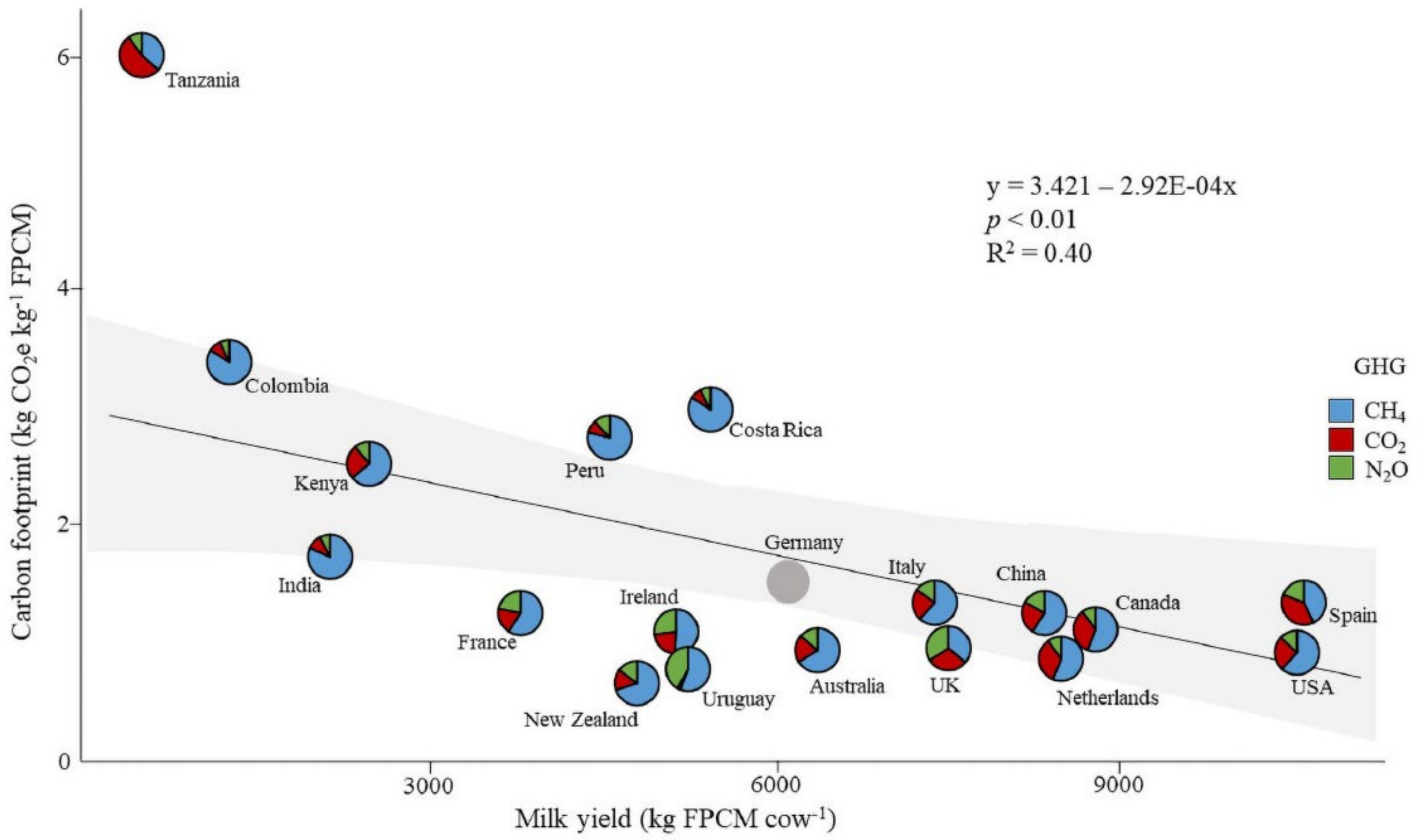


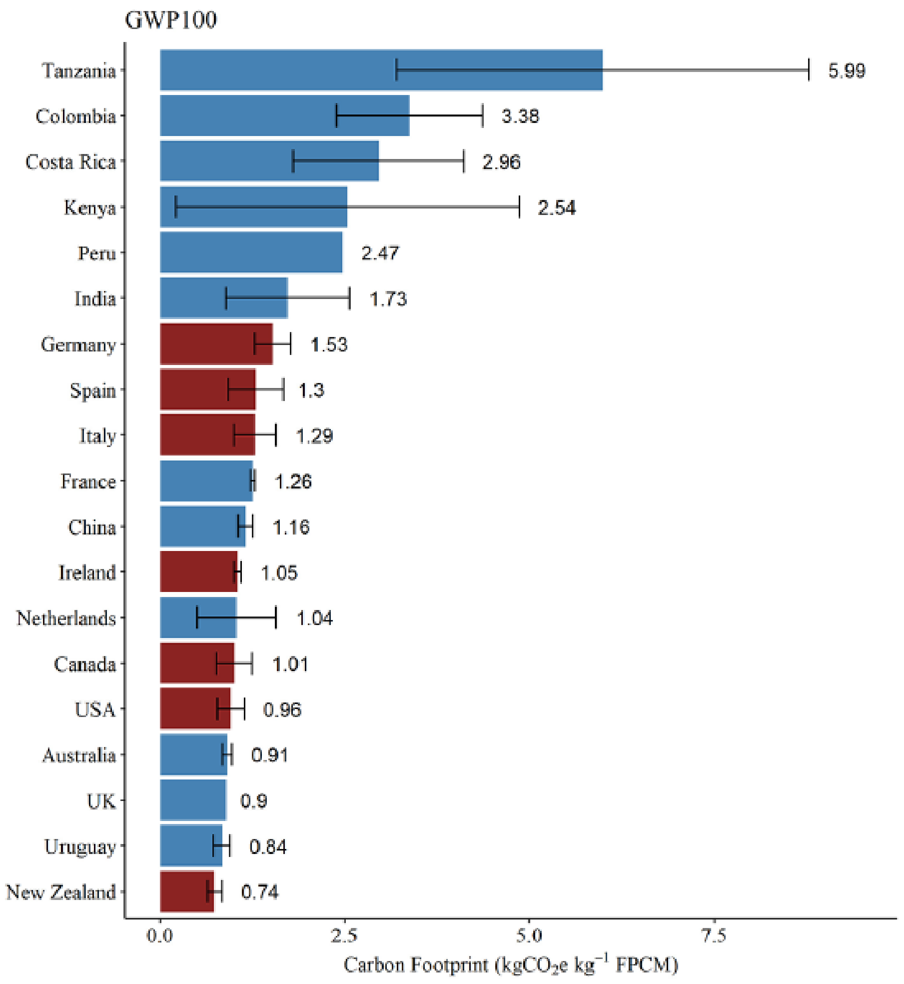

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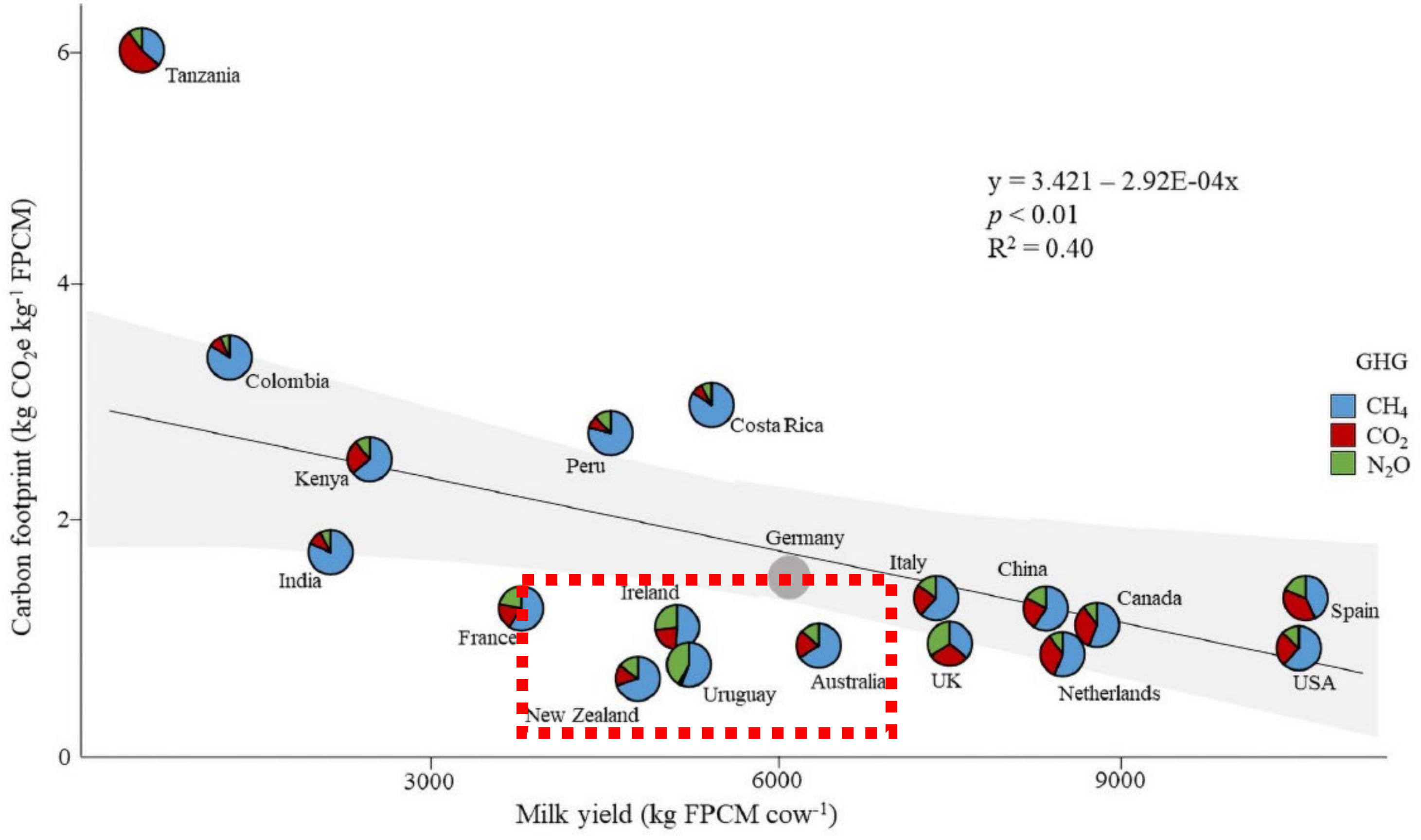


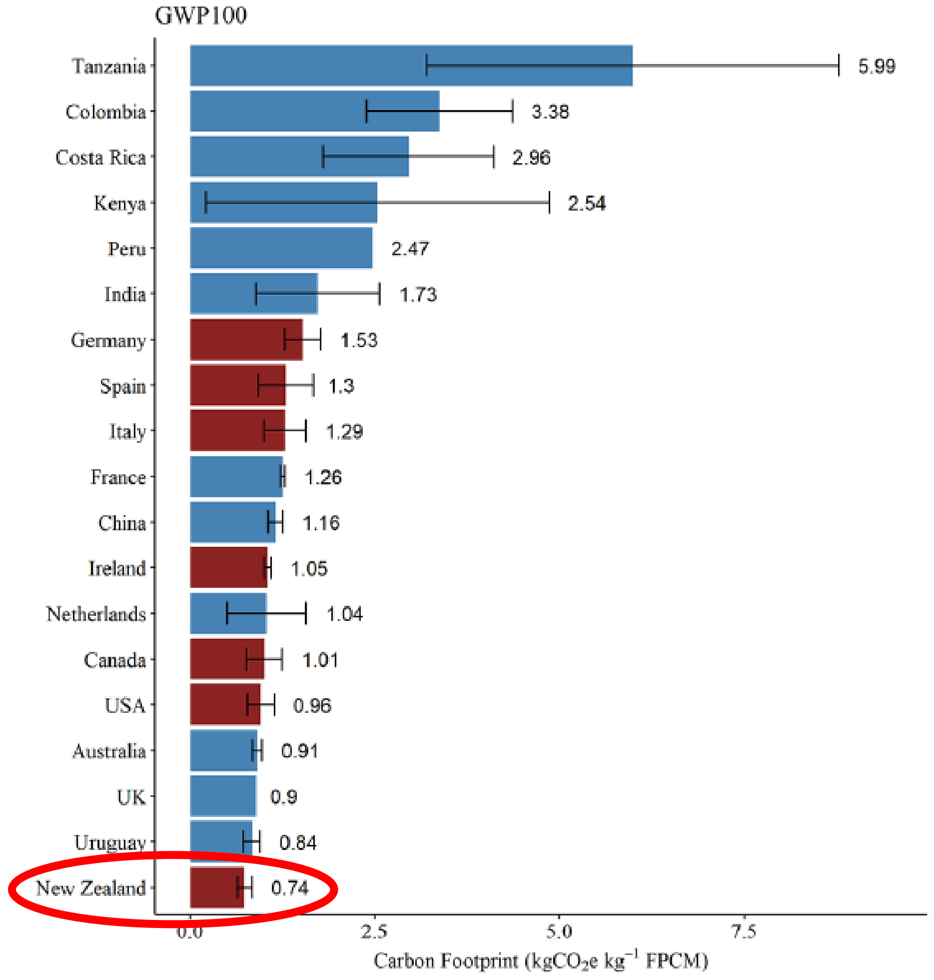

# Summary

- Growing global population and need for food security;
- Complete circularity is not possible;
- Focus is on reducing losses of N, P, and C to near zero;
- Food must be produced where it is most efficient to do so;
- Removal of barriers to trade.

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Thought for the Day

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“***It is easier to build strong children than to repair broken men***”

- Frederick Douglas