National Science Challenges

OUR LAND AND WATER

Toitū te Whenua, Toiora te Wai

Our Land and Water National Science Challenge

Toitū te Whenua Toiora te Wai

Innovative Agricultural Microbiomes

Graeme Attwood, Linda Johnson, Suzanne Rowe; AgResearch

Pablo Gregorini, Grant Edwards, Keith Cameron; Lincoln University

Pierre Beukes; Dairy NZ

Gwen Grelet; Landcare Research

Sergio Morales, University of Otago

"To enhance primary sector production and productivity while maintaining and improving our land and water quality for future generations"

Microbiomes are important drivers of nutrient cycles in agricultural production systems

Microbes evolved on earth more than 3.5 billion years ago

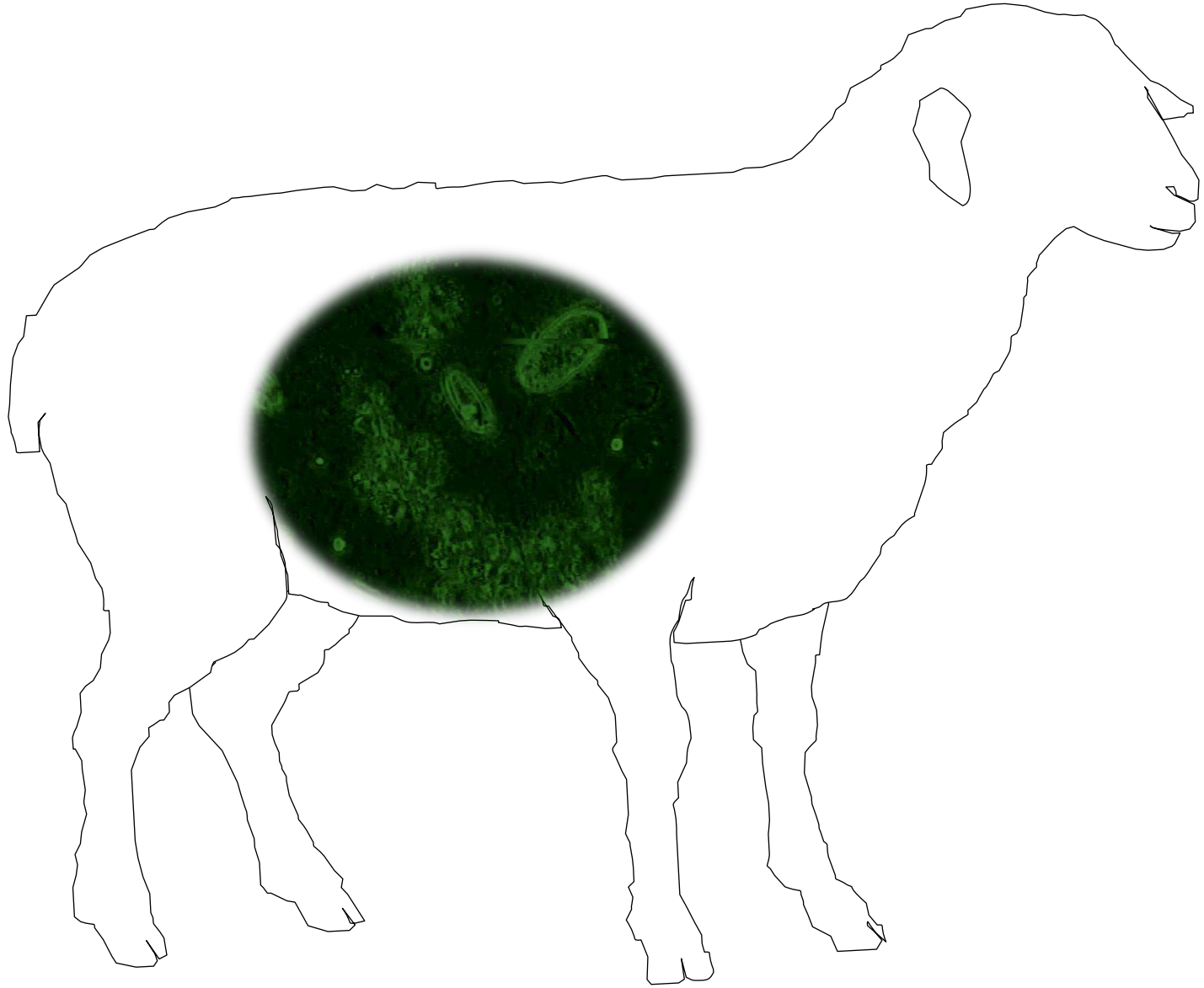
Microbes have contributed to the evolution and functioning of all other living organisms

Microbes drive the Earth's nutrient cycles,

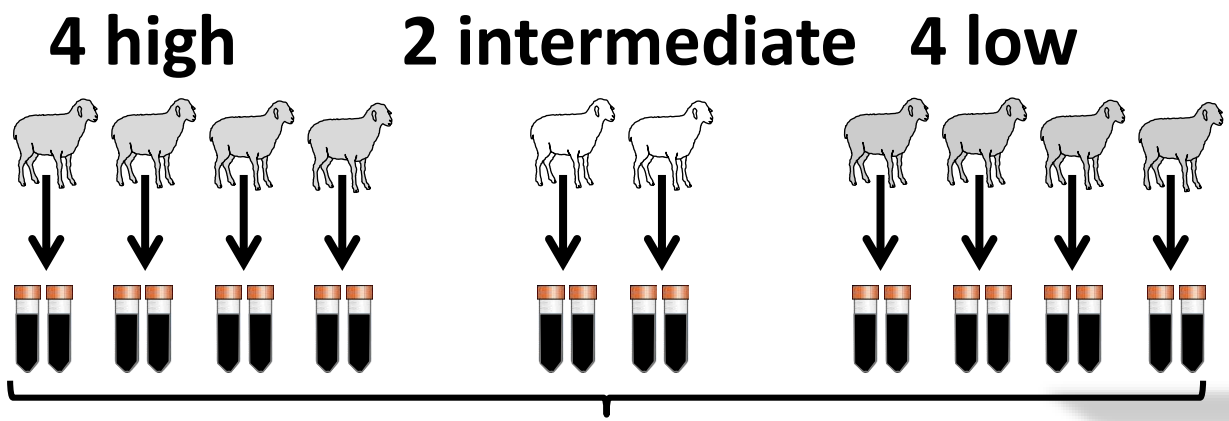
- carbon cycle, via transformation, storage, and release of terrestrial carbon stocks
- nitrogen cycle, via fixation of atmospheric N_2, nitrification to nitrates, and denitrification to N_2O and back to N_2.

In agriculture, microbiomes associated with soil, water, plants, and animals contribute significantly to productivity [1-7]

[1]Brulc et al., 2009, [2]Shi et al., 2014, [3]Kamke et al., 2016; [4]Kittelmann et al., 2014; [5]Morrison et al., 2009; [6]Johnson et al., 2013; [7]Dignam et al 2016.



Methane emission measurements and rumen sampling



CSH PRESS GENOME RESEARCH
doi:10.1101/gr.168245.113

Research

Methane yield phenotypes linked to differential gene expression in the sheep rumen microbiome

Weibing Shi,[1,2] Christina D. Moon,[3] Sinead C. Leahy,[3] Dongwan Kang,[1,2] Jeff Froula,[1,2] Sandra Kittelmann,[3] Christina Fan,[1,2] Samuel Deutsch,[1,2] Dragana Gagic,[3] Henning Seedorf,[3] William J. Kelly,[3] Renee Atua,[3] Carrie Sang,[3] Priya Soni,[3] Dong Li,[3] Cesar S. Pinares-Patiño,[3] John C. McEwan,[3] Peter H. Janssen,[3] Feng Chen,[1,2] Axel Visel,[1,2,4] Zhong Wang,[1,2,4] Graeme T. Attwood,[3] and Edward M. Rubin[1,2]

[1]Department of Energy, Joint Genome Institute, Walnut Creek, California 94598, USA; [2]Genomic Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA; [3]AgResearch Limited, Grasslands Research Centre, Palmerston North 4442, New Zealand; [4]School of Natural Sciences, University of California, Merced, California 95343, USA

20 rumen samples over two time points

Who's there and what can they do?

What are they doing?

Rumen microbial DNA

Rumen microbial RNA

Rumen microbiome analysis of low vs high methane yield sheep

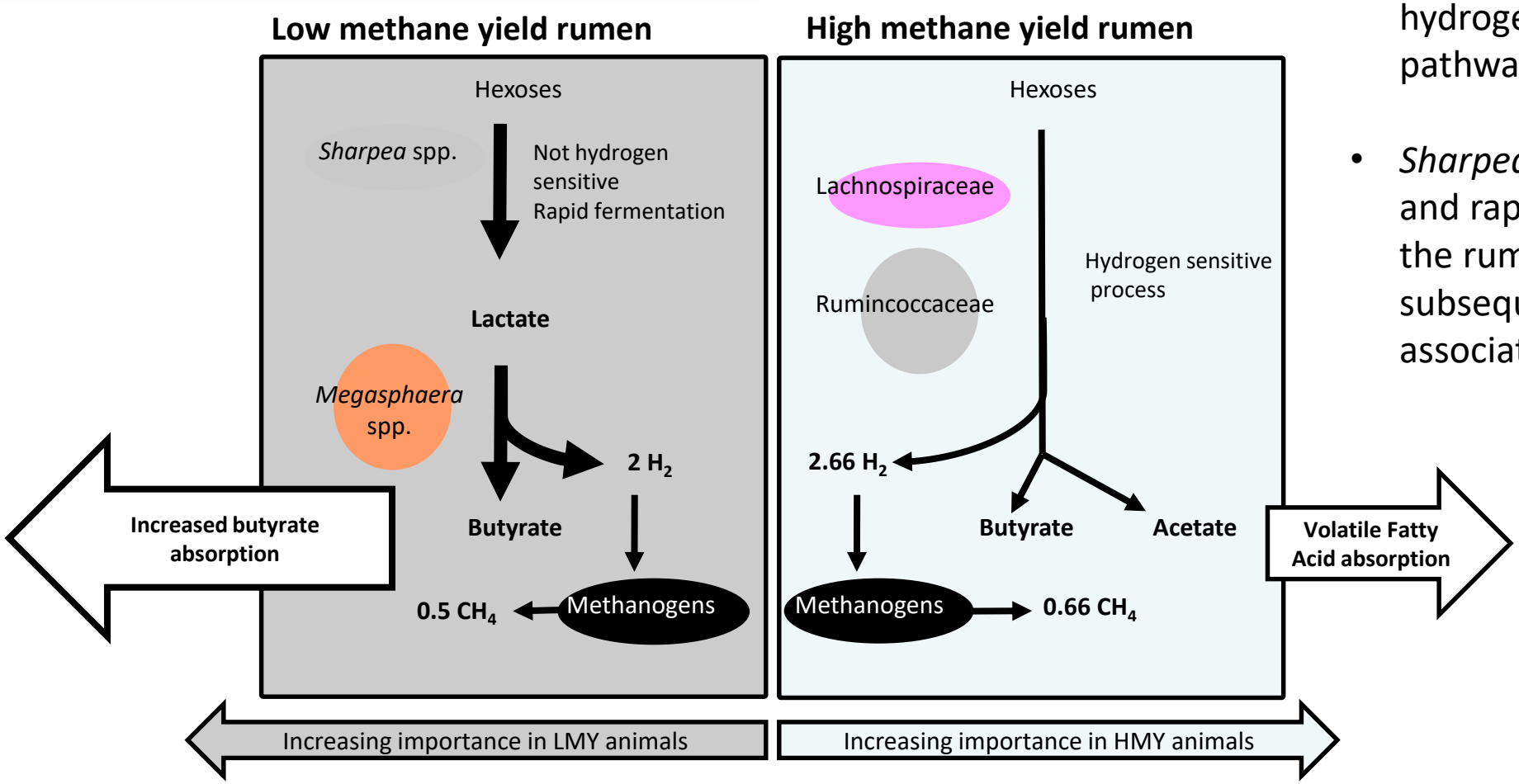
Microbiome
December 2016, 4:56

Rumen metagenome and metatranscriptome analyses of low methane yield sheep reveals a *Sharpea*-enriched microbiome characterised by lactic acid formation and utilisation

Authors Authors and affiliations

Janine Kamke, Sandra Kittelmann, Priya Soni, Yang Li, Michael Tavendale, Siva Ganesh, Peter H. Janssen, Weibing Shi, Jeff Froula, Edward M. Rubin, Graeme T. Attwood

- *Methanosphaera* elevated in LMY animals and *Methanobrevibacter gottschalki* elevated in HMY animals.
- Strong up-regulation of the hydrogenotrophic methanogensis pathway
- *Sharpea*-enriched bacterial community and rapid heterofermentative growth in the rumen with lactate formation and subsequent metabolism to butyrate associated with LMY sheep



NZ dairy production systems are strongly influenced by inputs to the nitrogen cycle

- atmospheric nitrogen fixed by legumes
- recycled dairy cow effluent
- nitrogenous fertilisers
- made available through the action of microbes
  - via N_2-fixing bacteria associated with plants,
  - via protein-, peptide-, and amino acid-degrading bacteria in the rumen
  - by ammonifying and nitrifying bacteria in the soil

Innovative Agricultural Microbiomes

Hypothesis: efficient use of nitrogen in a RG-WC dairy production system is controlled by the composition, activity and interaction between soil, plant and animal microbiomes that mediate nitrogen transactions in these environments.

Research questions:

- What are the main structural and functional characteristics of agricultural microbiomes and how do they respond to increasing levels of nitrogenous fertiliser?
- What are the key soil-plant-animal microbiome interactions that impact on improved pasture and animal productivity and on water quality?
- Which features of agricultural microbiomes can be managed to improve productivity and water quality?
- Are there bio-indicators of microbiome interactions that can be used to track agricultural productivity and water quality?

Planned research activities and principal investigators

Farm operation, animal management, plant and milk (production and composition) measurements. Prof. Pablo Gregorini, Lincoln University

Farm systems modelling. Dr Pierre Beukes, DairyNZ.

Soil microbiome analyses. Dr Gwen Grelet, Landcare Research.

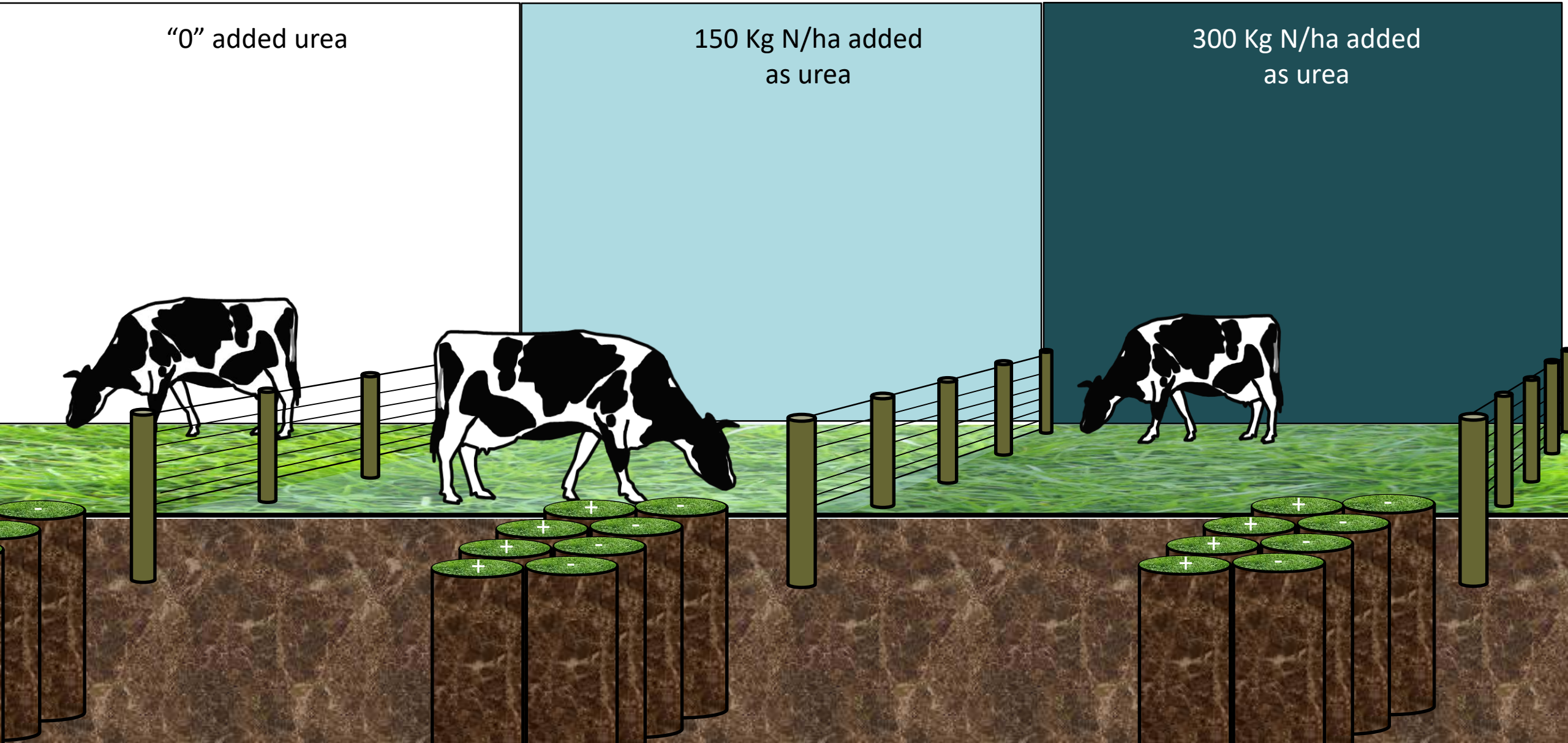
Above ground plant (phylosphere) and internal root microbiome analysis. Dr Linda Johnson, AgResearch Grasslands.

Rumen and faecal microbiome analyses. Dr Graeme Attwood, AgResearch Rumen Microbiology, Grasslands.

Amplicon, metagenome and metatranscriptome sequencing of microbiome samples. Dr Suzanne Rowe, AgResearch Animal Genomics, Invermay.

Comparative microbiome and network analyses. Dr Sergio Morales, Dept. Microbiology, Otago University.

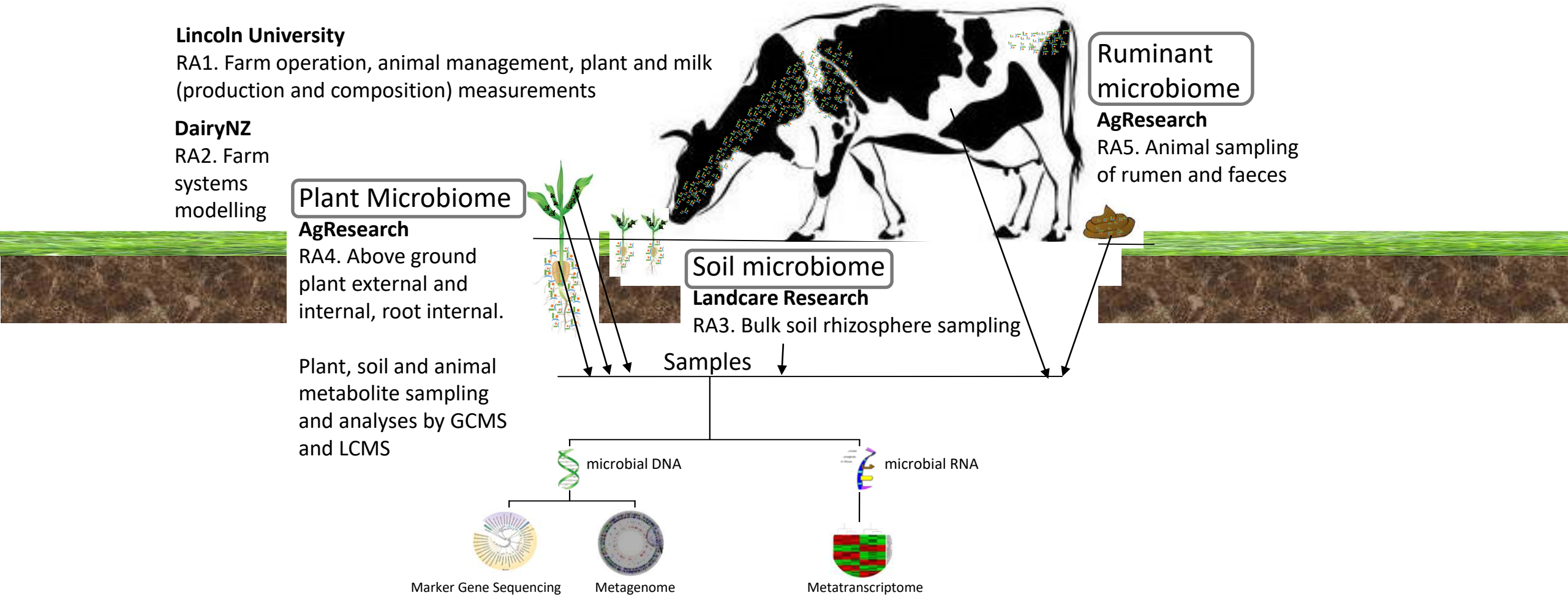
Experimental plan



Microbiome sampling, nucleic acids extraction and sequencing

Lincoln University
RA1. Farm operation, animal management, plant and milk (production and composition) measurements

DairyNZ
RA2. Farm systems modelling



AgResearch
RA5. Animal sampling of rumen and faeces

AgResearch
RA4. Above ground plant external and internal, root internal.

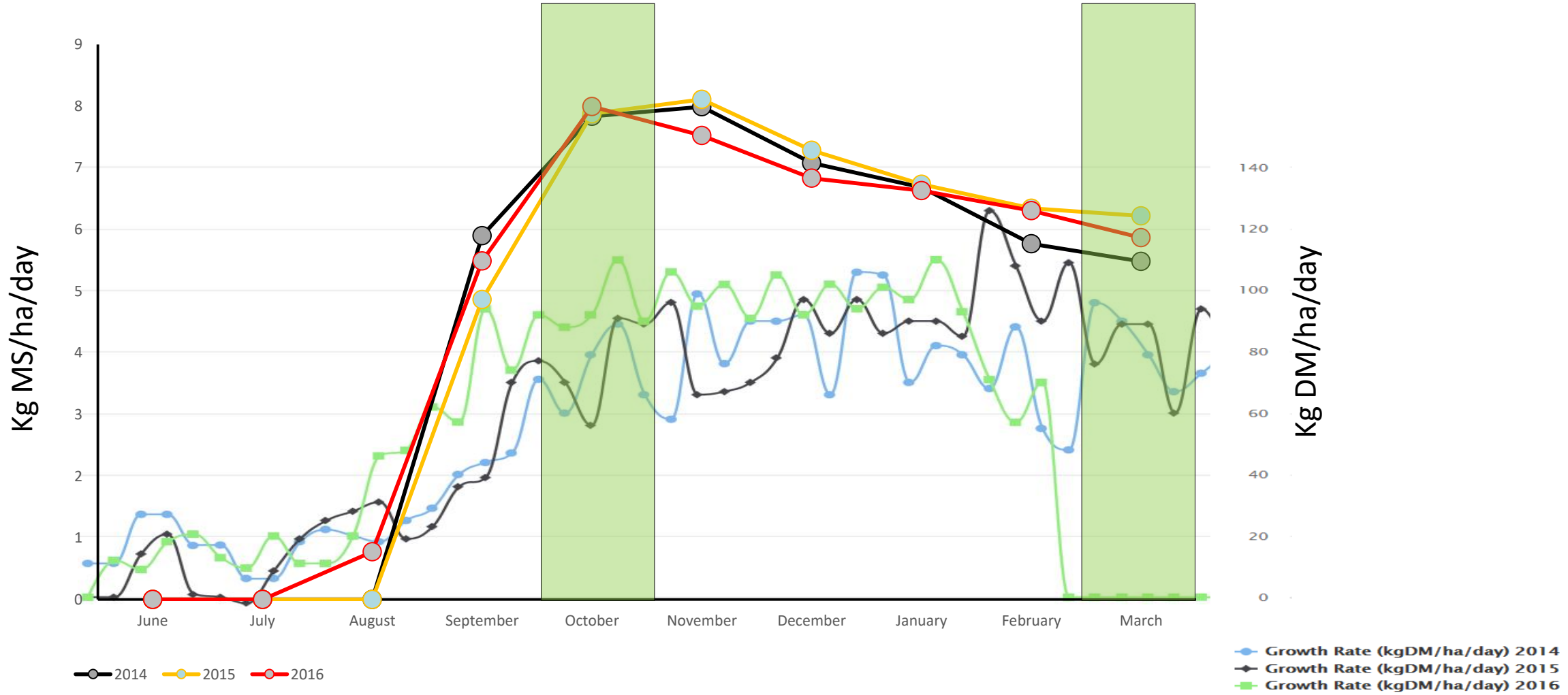
Landcare Research
RA3. Bulk soil rhizosphere sampling

Plant, soil and animal metabolite sampling and analyses by GCMS and LCMS

AgResearch
RA6. DNA/RNA library constructions, sequencing, data management, analyses

Otago University
RA7. Comparative microbiome analyses, network analyses

Timing of sampling



LUDF production data, SIDDC: http://www.siddc.org.nz/lu-dairy-farm/milkproductiondata/

Integration with the value chain concept

The IAM programme seeks to:

- Investigate how microbiome opportunities can enhance performance of farm operations
- provide new data on credence attributes for product verification schemes
- support claims that NZ's pastoral farming systems can be "natural and sustainable" (i.e. the microbial diversity and functional characteristics of productive and sustainable systems)
- work with the Integrated Value Chain programme to examine whether microbiome characteristics can contribute to mātauranga Māori-informed attributes of soil, animal and plant health that can be used to "brand" Māori agribusiness products, build a value proposition of credence attributes associated with agricultural microbiome characteristics

Engagement with end users

- The IAM programme is at the discovery end of the science spectrum therefore end users will include scientists within aligned programmes as well as within the OLW NSC.
- DairyNZ scientists have co-developed the OLW-IAM programme, enabling co-innovation with industry, to address issues of relevance to dairy farm production systems.
- IAM will consult with developers of OVERSEER, APSIM, and DairyNZ's whole farm model, to translate and use our microbiome data.
- Data will be deposited in the Biological Heritage eDNA virtual hub and be available to all stakeholders and end-users.
- Awareness in the farming community and agribusinesses will be raised through a field day at Ashley Dene farm and articles will be published in the popular press and media.

Vision Mātauranga

- The concept of Māuri (the life force) recognises how all things on earth are connected and interdependent.
- Microbiomes are consistent with Māuri and serve to link together the soil, plants and animals within agricultural production systems.
- IAM will work with the Integrated Value Chain programme to examine whether microbiome characteristics can contribute to mātauranga Māori-informed attributes of soil, animal and plant health that can be used to “brand” Māori agribusiness products
- Raise awareness of these attributes with Waka Kai Ora and Miraka.
- Test the acceptance of these attributes through discussions with Ngai Te Ruahikihiki ki Taumutu via the aligned MBIE “Reducing nitrogen losses from farms” programme led by Dr David Whitehead, Landcare Research.

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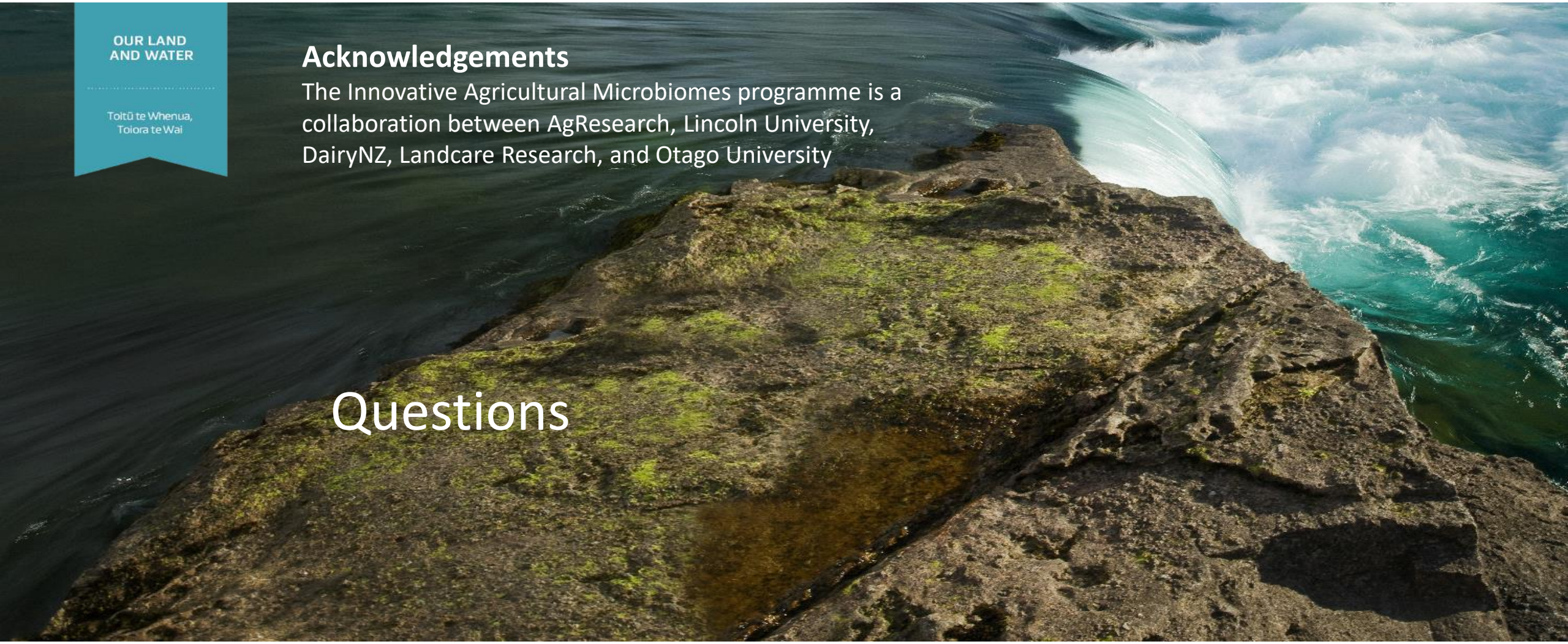
Acknowledgements

The Innovative Agricultural Microbiomes programme is a collaboration between AgResearch, Lincoln University, DairyNZ, Landcare Research, and Otago University



Questions