Our Land and Water National Science Challenge

Toitū te Whenua Toiora te Wai

Innovative Agricultural Microbiomes

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“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 N₂, nitrification to nitrates, and denitrification to N₂O and back to N₂.

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

¹Brulc et al., 2009, ²Shi et al., 2014, ³Kamke et al., 2016; ⁴Kittelmann et al., 2014; ⁵Morrison et al., 2009; ⁶Johnson et al., 2013; ⁷Dignam et al 2016.
Methane emission measurements and rumen sampling

Who’s there and what can they do?

Rumen microbial DNA

What are they doing?

Rumen microbial RNA

4 high

2 intermediate

4 low

20 rumen samples over two time points

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

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Rumen microbiome analysis of low vs high methane yield sheep

- **Methanosphaera** elevated in LMY animals and **Methanobrevibacter gottschalki** elevated in HMY animals.

- Strong up-regulation of the hydrogenotrophic methanogenesis 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

“0” added urea

150 Kg N/ha added as urea

300 Kg N/ha added as urea
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**
RA4. Above ground plant external and internal, root internal.

**Plant Microbiome**
AgResearch
RA3. Bulk soil rhizosphere sampling

**Soil microbiome**
Landcare Research
RA5. Animal sampling of rumen and faeces

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

**Otago University**
RA7. Comparative microbiome analyses, network analyses

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

Samples

- microbial DNA
- microbial RNA

Marker Gene Sequencing, Metagenome, Metatranscriptome
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.
Acknowledgements
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Questions