Soil research advances in Aotearoa 2020

Bryan Stevenson & Sam Carrick

On behalf of NZ Soil Science

Manaaki Whenua Landcare Research

Slide Contributors

Plant & Food Research
AgResearch
Lincoln Uni
Auckland University
Manaaki Whenua
Massey University
Waikato University

Steve Thomas
Mike Beare
Karin Mueller
Denis Curtin
Sam McNally
Dave Houlbrooke
Alec Mackay
Nicole Schon
Ronaldo Vibrat
Kirstin Deuss
Balin Robertson
Keith Cameron
Gavin Lear
Paul Mudge
James Barringer
Dave Horne
Lucy Burkitt
Chris Anderson
Louis Schipper

Runsheet

1. Soil mapping
2. Soil carbon
3. Soil management
4. Soil biology & health

S-map

353,000 ha added last year

36.6% of total NZ or c. 50% of the 'farmable land'

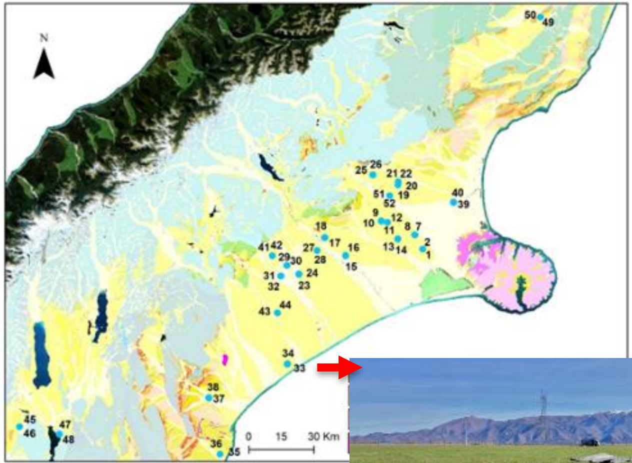
New S-map soil water attribute model released August 2020

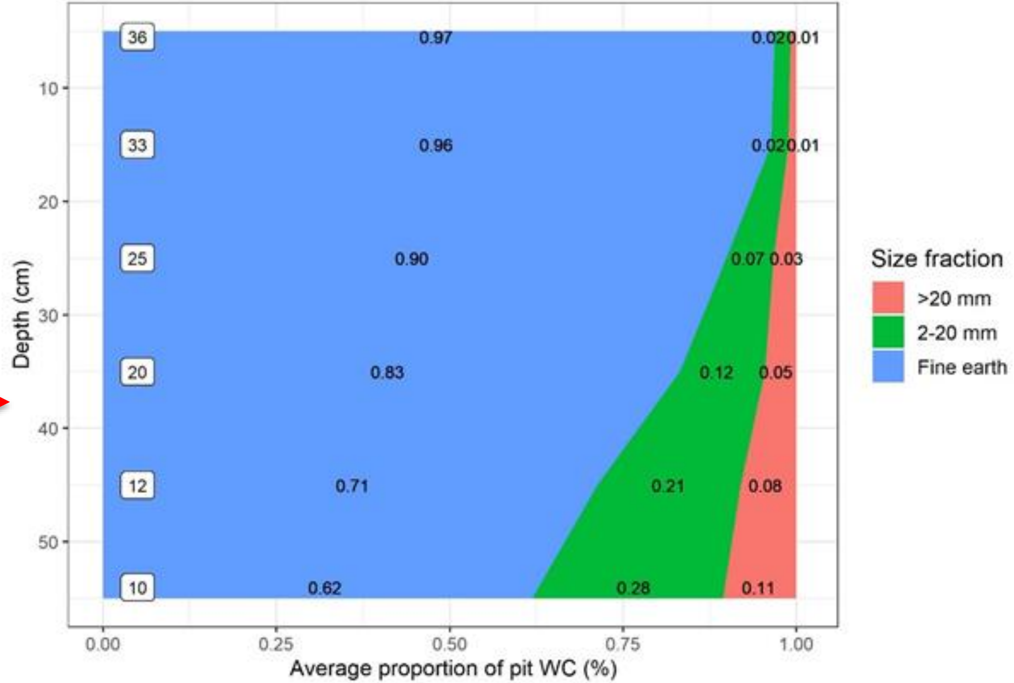
Usage is growing and growing

carricks@landcareresearch.co.nz

Balin Robertson PhD: Role of stones in soil water storage

Case study: Canterbury stony soils





Finding: Stones account for about 10% of soil profile water to 60cm depth

Balin.Robertson@lincolnuni.ac.nz, carricks@landcareresearach.co.nz

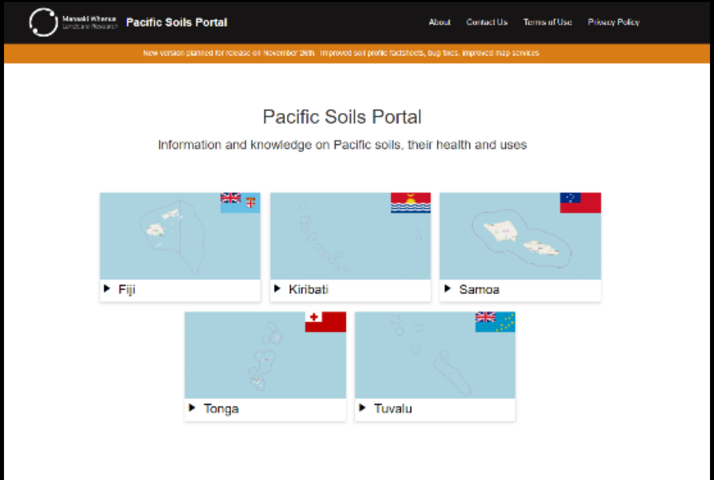
How soil water porosity changes under irrigation

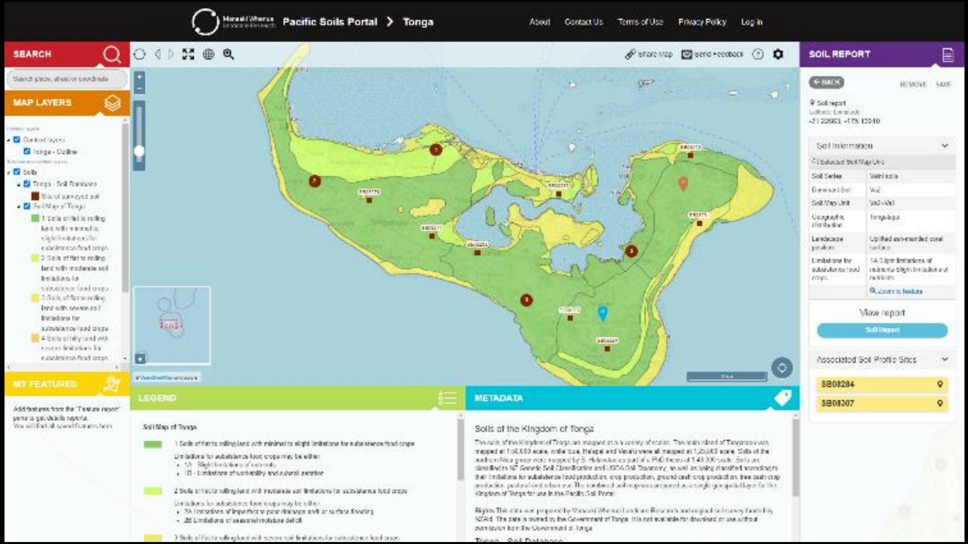
- Paired sites across Canterbury (Dry v Irrigated in same paddock)
- Total water storage showed some increase in irrigated soil
- Irrigated sites were more compacted
- Loss of readily available storage pores = farmers need to irrigate more often

carricks@landcareresearch.co.nz

Pacific Soil Portal

https://psp.landcareresearch.co.nz





Legacy soil maps and soils data available to all users via web browser on PC, laptop, Tablet or phone.

barringerj@landcareresearch.co.nz

Soil Carbon

New national soil C benchmarking & monitoring programme

About 100 sites in each of five broad land use classes:

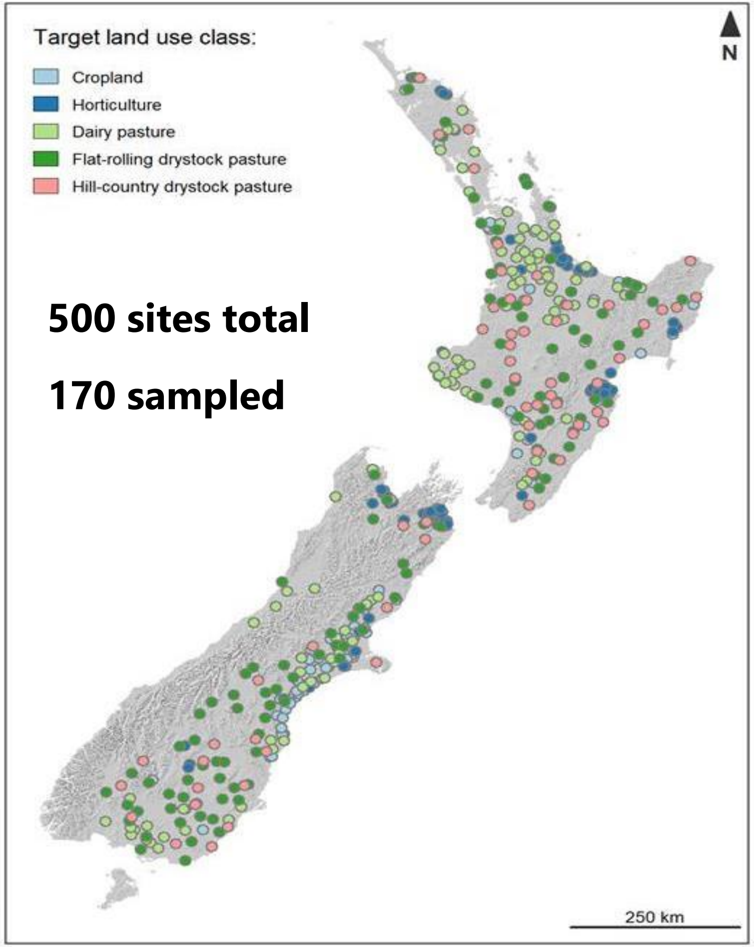
- Cropland
- Horticulture
- Dairy pasture
- Flat-rolling drystock
- Hill-country drystock

Sites randomly selected to avoid potential bias

Sampling to 0.6 m depth on a 4-year rolling schedule

- Benchmarking complete by 2023
- Three sampling points for all sites by 2031

Designed to be able to detect a change of 2 t/ha for each broad land use class, should such a change occur



Ministry for Primary Industries
Manatū Ahu Matua

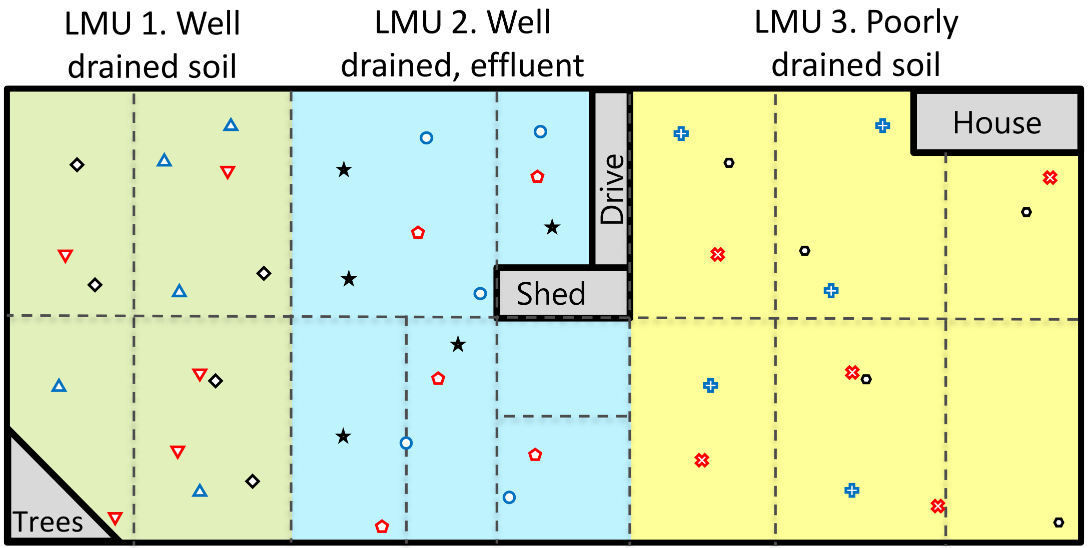
NEW ZEALAND
AGRICULTURAL GREENHOUSE GAS
Research Centre

mudgep@landcareresearch.co.nz

Farm-scale soil C benchmarking and monitoring

Similar approach to the national scale system:

- Use land management units (LMU) in farm environment plans
- Random allocation of sampling sites across the LUMs



- Same soil sampling and processing methods
- Data could compliment the national scale programme

Ministry for Primary Industries
Manatū Ahu Matua

Mudge, P.L., McNeill, S., Hedley, C., Roudier, P., Poggio, M., Malone, B., Baldock, J., Smith, P., McNally, S., Beare, M., Schipper, L., 2020. Design of an on-farm soil carbon benchmarking and monitoring approach for individual pastoral farms. **MPI Technical Paper No: 2020/02.**

Long-term changes in soil carbon stocks in hill pastures

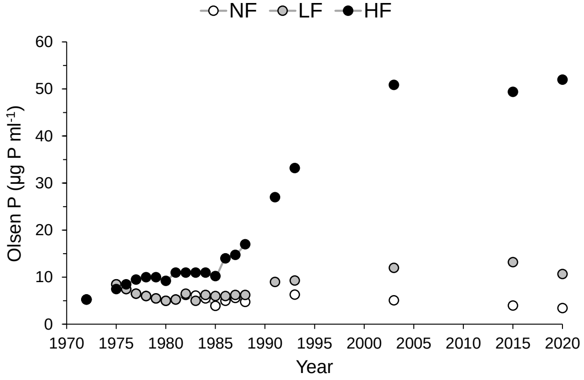
Farmlets:

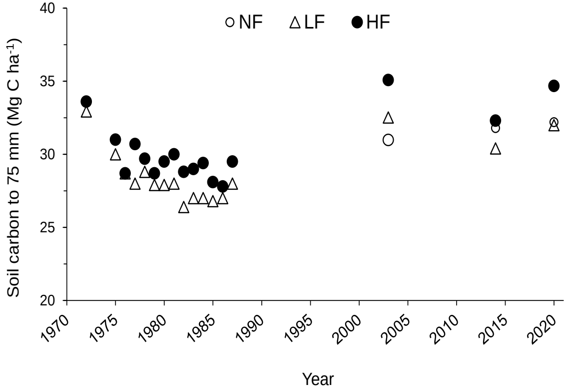
- NF = No P fertiliser
- LF = 125 kg P fertiliser ha^{-1} y^{-1}
- HF = 375 kg P fertiliser ha^{-1} y^{-1} since 1980

Grazed with breeding ewes since 1975

- 6.9, 9.8, 15.9 SU ha^{-1} on NF, LF, HF (1980 – 2020)

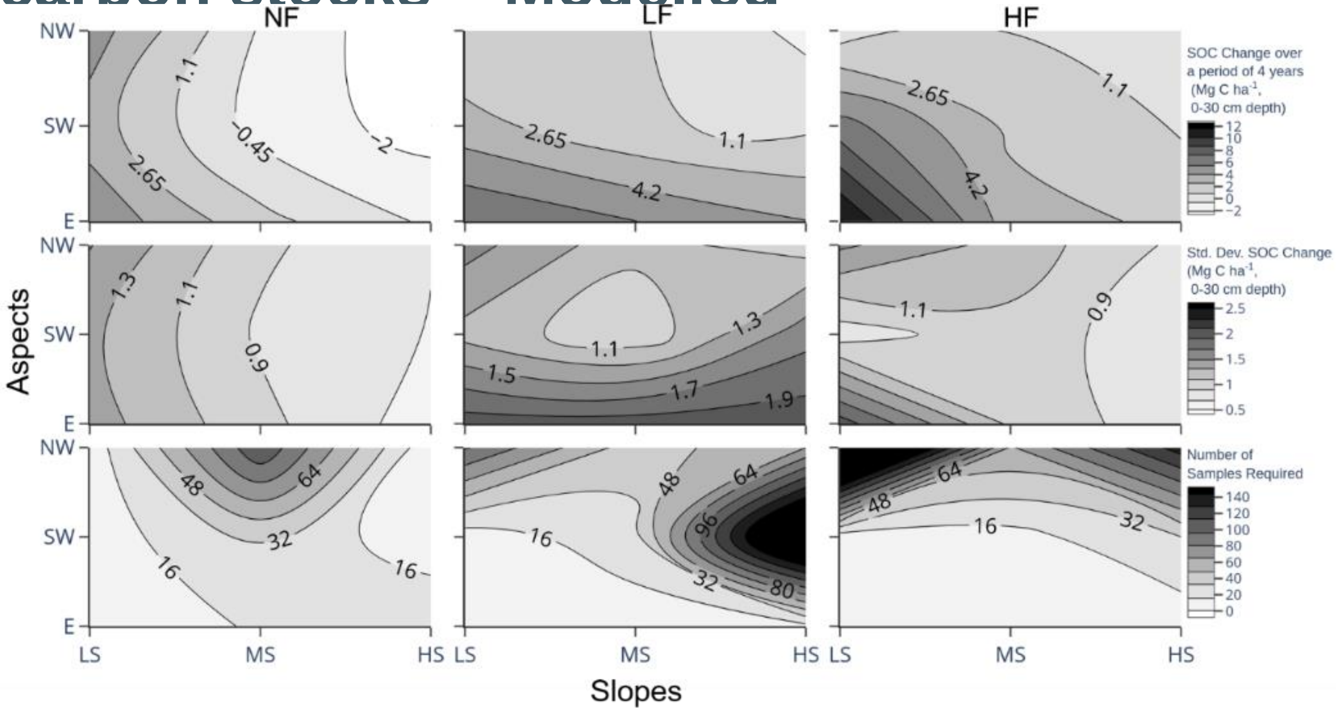
Soil depth	Soil C stocks (Mg C ha^{-1})			p-value ≤
(mm)	NF	LF	HF	
0-75	31.6	31.7	34.0	0.07
75-150	30.2	29.7	29.8	0.93
150-300	50.2	48.6	47.3	0.59
0-300	111.1	109.8	111.5	0.94





alec.mackay@agresearch.co.nz , Ronaldo.Vibart@agresearch.co.nz

Soil carbon stocks – Modelled

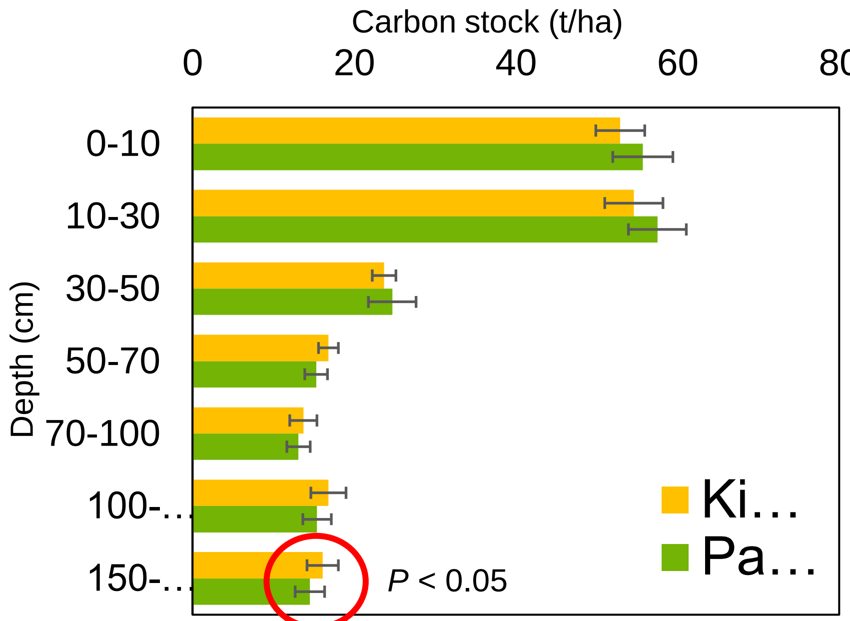


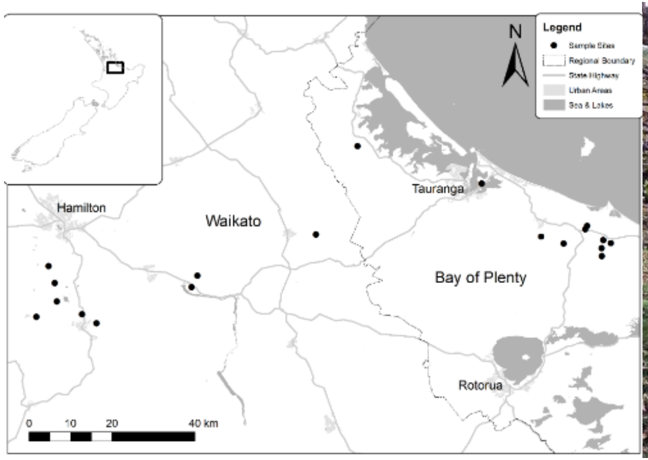
Modelled SOC changes, SD and No. samples required over a period of 4 years [NF (no SSP applied); LF (125 kg SSP ha^{-1}); HF (375 kg SSP ha^{-1}), since 1980], as affected by slope (LS = low slope, MS = medium slope, HS = high slope) and aspect (E = east, SW = southwest, NW = northwest)

alec.mackay@agresearch.co.nz , Ronaldo.Vibart@agresearch.co.nz

Deep soil carbon stocks under kiwifruit and pasture

- Do subsoil carbon stocks increase under kiwifruit production?
  - Paired-site study of 19 sites in Waikato and Bay of Plenty
  - Kiwifruit land use modestly increased subsoil carbon and nitrogen (1.5–2.0 m depth)
  - Cumulative stocks to a depth of 2 m were not different between land uses

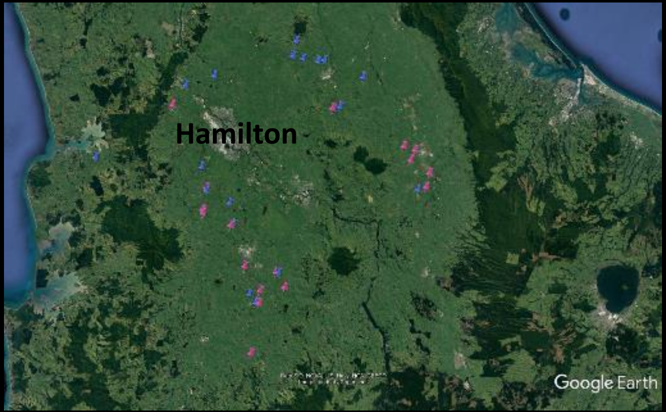




Gentile et al. 2021. Agric. Ecosyst. Environ. 306: 107190

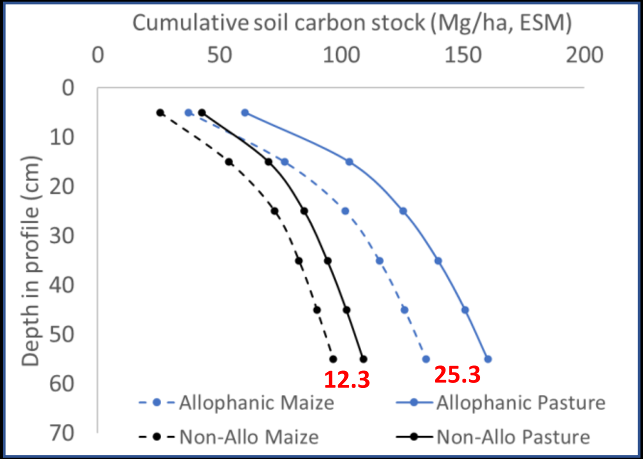
Roberta.Gentile@plantandfood.co.nz

Waikato Maize – Pasture soil carbon comparison
(preliminary results)



42 paired sites
- 19 Allophanic
- 23 non-Allophanic

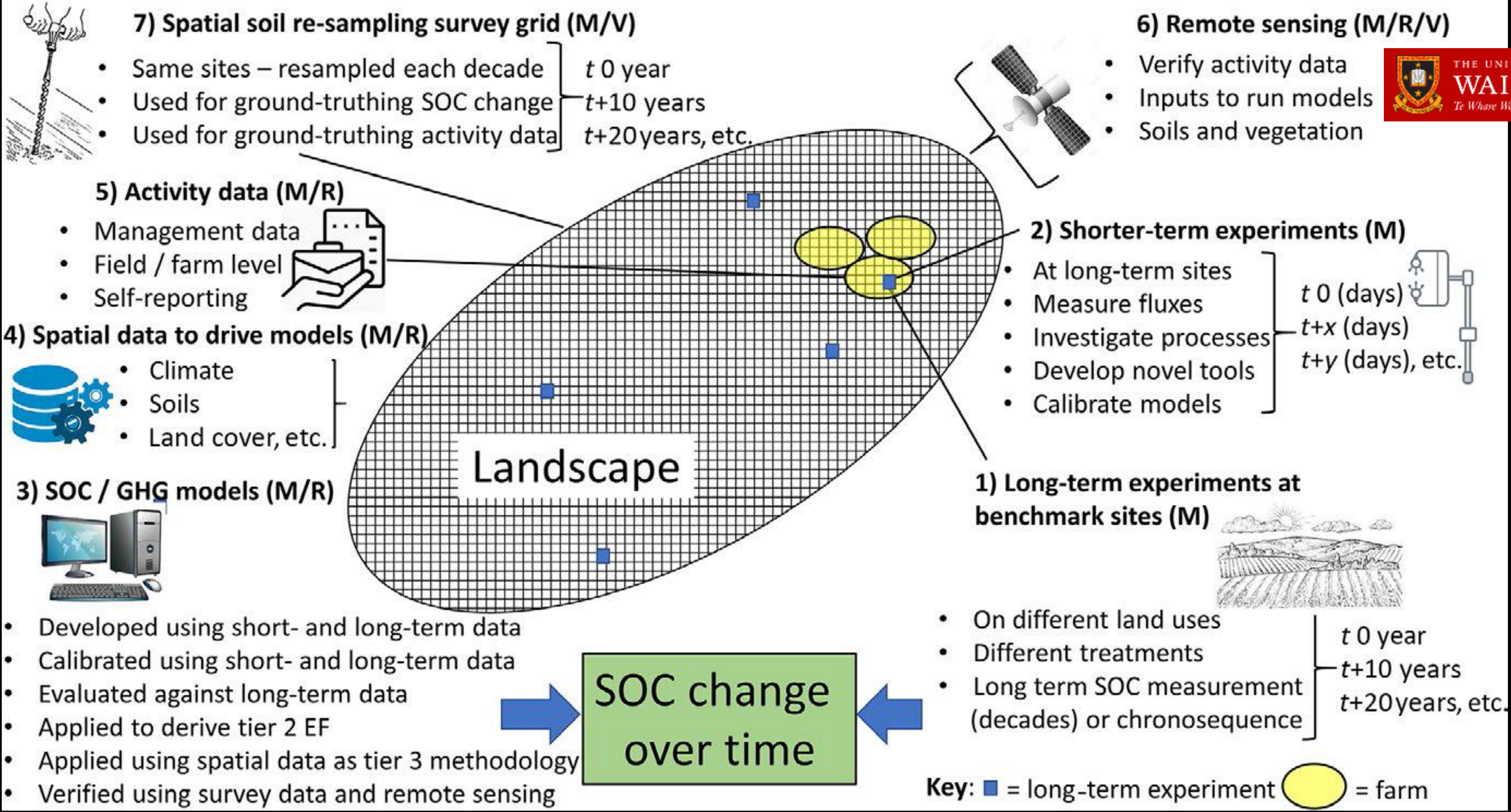
Sampled to 60 cm



- Less carbon under maize
- Greater loss in Allophanic Soils
- Main difference in top soil

(Mudge et al., in prep)

mudgep@landcareresearch.co.nz



Smith, P.; Soussana, J-F.; Angers, D.; **Schipper**, L.A.; … **McNeill**, S.; et al. (2020). Global Change Biology. 26:219–241.

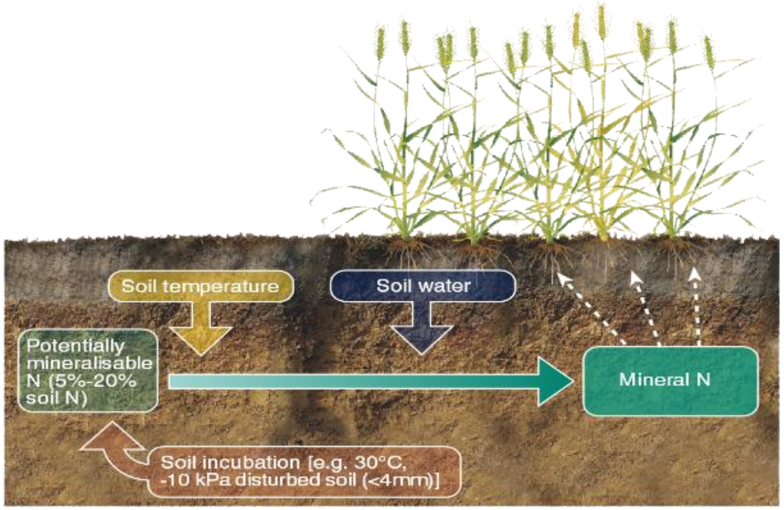
schipper@waikato.ac.nz

Soil Management

Soil N Testing to Improve Fertiliser N Use Efficiency

- ➢ Good N management is important meet crop and regulatory needs
- ➢ SOM can be important source plant available N
  - ▪ But testing & predicting N mineralisation is challenging
- ➢ Plant & Food Research has developed a new test to predict supply of plant-available N
- ➢ SFF project underway
  - ▪ On-farm trials to verify test
  - ▪ Increase farmer awareness
  - ▪ Calibrate the test for commercial release

For further information: Mike.Beare@plantandfood.co.nz



Managing irrigation and nutrients on loess hillslope soils

- Irrigation - increasing scale and intensification
  - Now covers tens of thousands ha in South Canterbury and North Otago
- Loess hill slopes behave differently to traditional flatland irrigation areas
  - Runoff is more important than drainage
- Management options:
  - Reduce irrigation on slopes/valley floor - VRI
  - Improved soil water budgeting, modelling and sensing
  - Mitigation focussed on runoff flowpaths

Steve.Thomas@plantandfood.co.nz

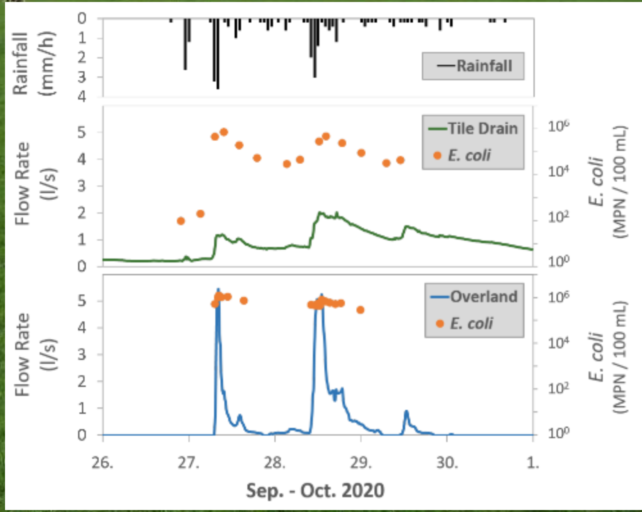
Manaaki Whenua Landcare Research | EARTH & ENVIRONMENTAL SCIENCE | Environment Canterbury Regional Council | agresearch | NIWA | LINCOLN UNIVERSITY

Kirstin Deuss PhD: Soil hydraulic properties and water quality in mole-drained loess drainage basin

Manaaki Whenua Landcare Research

environment SOUTHLAND REGIONAL COUNCIL Te Taiao Tonga

Lincoln University Te Whare Wānaka o Aoraki



Kirstin.Deuss@lincolnuni.ac.nz, carricks@landcarereserach.co.nz

Investigating the ability of plantain to reduce nitrogen losses to the environment

Perennial ryegrass/white clover

0% Plantain | 30% Plantain | 50% Plantain | 70% Plantain

Measurements

Pasture
(ME, CP, NDF, WSC)

Animal
(Milk, urine, faeces, blood)

Soil
(Nitrate leaching)

Soledad Navarrete, Peter Kemp, Danny Donahy and Dave Horne

D.J.Horne@massey.ac.nz

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Overseer® model validation in high rainfall areas

Aim: Measure nitrogen (N) leaching from two similar farms under dairy cow grazing in the Lake Rotorua catchment with annual rainfall of over 2000 mm.

Contrasting free draining vs poorer draining pumice soils.

150 porous ceramic cups / farm to measure N concentration

Drainage measured using lysimeters

mike.sprosen@agresearch.co.nz

Ashley Dene large lucerne lysimeters

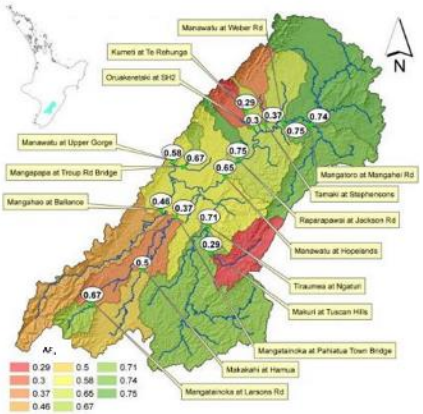
Irrigated vs Dryland

- 1.5 – 15x greater N loss from lucerne under irrigation + effluent
- 30% greater drainage volume under irrigation
- 1-3 t C/ha/y loss of soil C

grahams@landcareresearch.co.nz

Monitoring, mapping and managing Nitrate attenuation

Mapping variable attenuation



Bioreactor

Controlled drainage

Ranvir Singh and Dave Horne
D.J.Horne@massey.ac.nz

LINCOLN UNIVERSITY
TE WHARE WĀNAKA O AORAKI

ClearTech®

ravensdown

dairy effluent treatment system to recycle water and protect the environment

Produces:

(i) 'clarified water' that can be recycled to wash the farm yard, and
(ii) 'treated effluent' that is safer to apply to the land

- **ClearTech could save over 4 million litres of freshwater per farm per year**

Keith.Cameron@lincoln.ac.nz

Thomas Mackay-Smith (PhD): Can kānuka (*Kunzea* spp.) be integrated as a silvopastoral tree in hill country to improve soil quality?

Study one Martinborough

- compares soil moisture, soil fertility, soil carbon, soil physical conditions and pasture growth between pasture under kānuka and in open pasture

Study two Waipukurau

- compares runoff volume, nutrient and sediment loss between pasture under kānuka and in open pasture

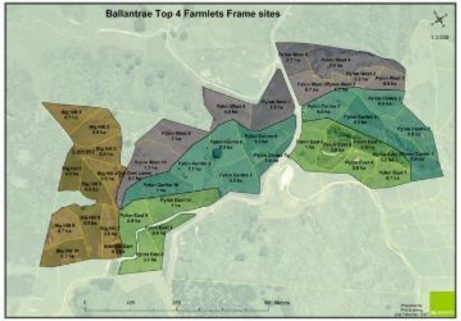
Soil Biology & Soil Health

agresearch ata mātai, mātai whetū

beef+lamb new zealand

Earthworms as indicators of soil health

www.earthworms.nz



Earthworm Indicator

For each land management unit

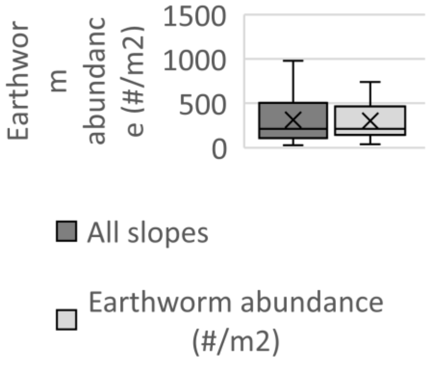
Are earthworm populations above 400/m²?

Yes / No

Is each earthworm functional group present above 25/m²

Yes / No

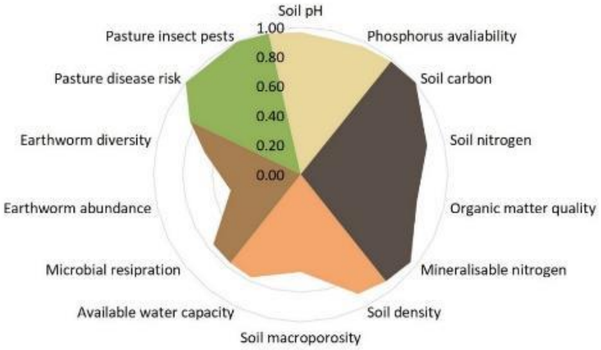
If you answered yes to both questions you have healthy earthworm populations.	If you answered no to either question your earthworm populations are lacking. Consider changing management practices to enhance populations. Consider introducing any missing earthworm functional groups.



Nicole.Schon@agresearch.co.nz

On-farm soil health assessment

- Conducted along the transects used to monitor soil fertility across the major land management units and soils on-farm
- Combination of laboratory and field assessment
- Indicators are linked to land use and management practices and wider outcomes
- Additional measures can be added to address specific issues (e.g. contaminants).



Base measures	Additional measures
Soil fertility	
Soil pH Olsen P Sulphate-S/organic S Potassium Magnesium	Trace elements/heavy metals
Soil organic matter	
Soil carbon	Soil nitrogen Soil C:N ratio Available carbon Available nitrogen
Soil physical condition	
Visual soil assessment (e.g. compaction, porosity & bare soil)	Water holding capacity Water infiltration Aggregate stability
Soil biological activity	
Earthworm abundance and diversity	Pasture pests and diseases Microbial biomass Nitrogen mineralisation

alec.mackay@agresearch.co.nz, Nicole.Schon@agresearch.co.nz

Samples for Sequencing

Indigenous

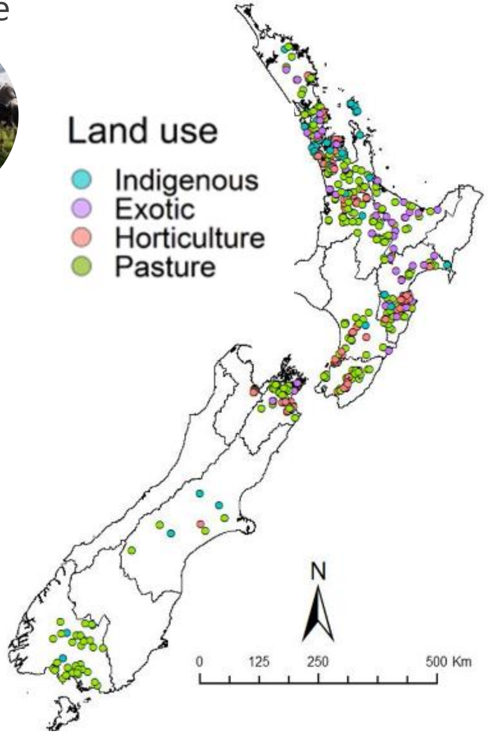
Exotic

Horticulture

Pasture

- 5,000 + soil samples collected from 670 sites
    - soil metadata: soil pH, nutrients, physical measures, heavy metals

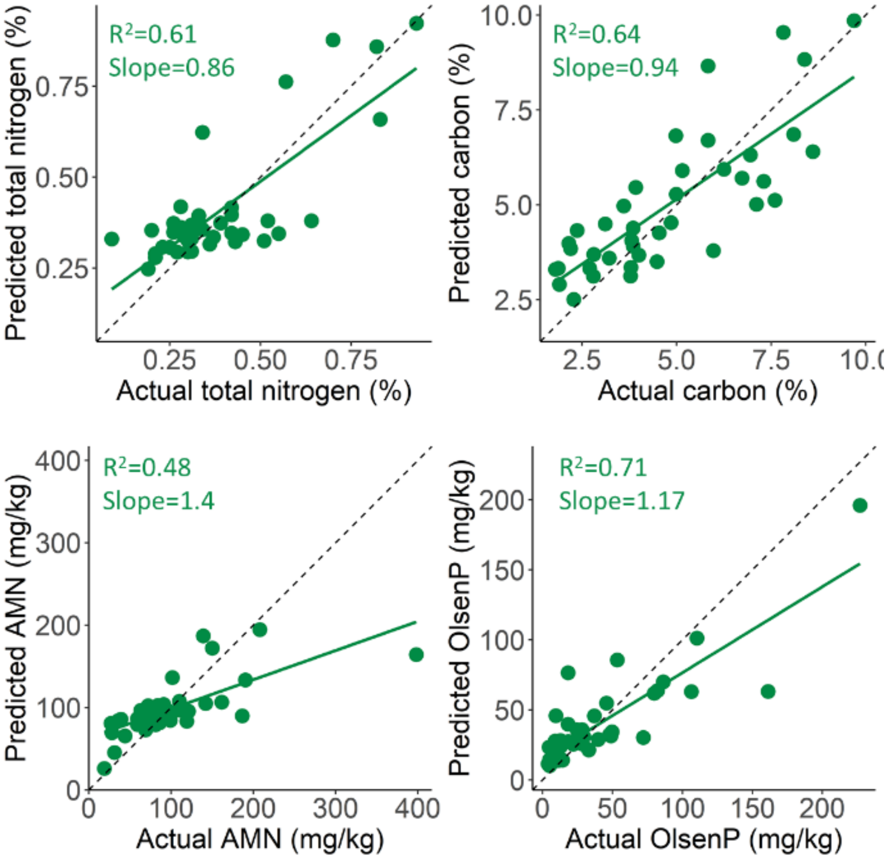
- 16S rRNA gene amplicon sequencing (V3-V4 region, MiSeq)



Syrie Hermans *et al*. (2020)

g.lear@auckland.ac.nz

Predicting Nutrient Status from metagenomics



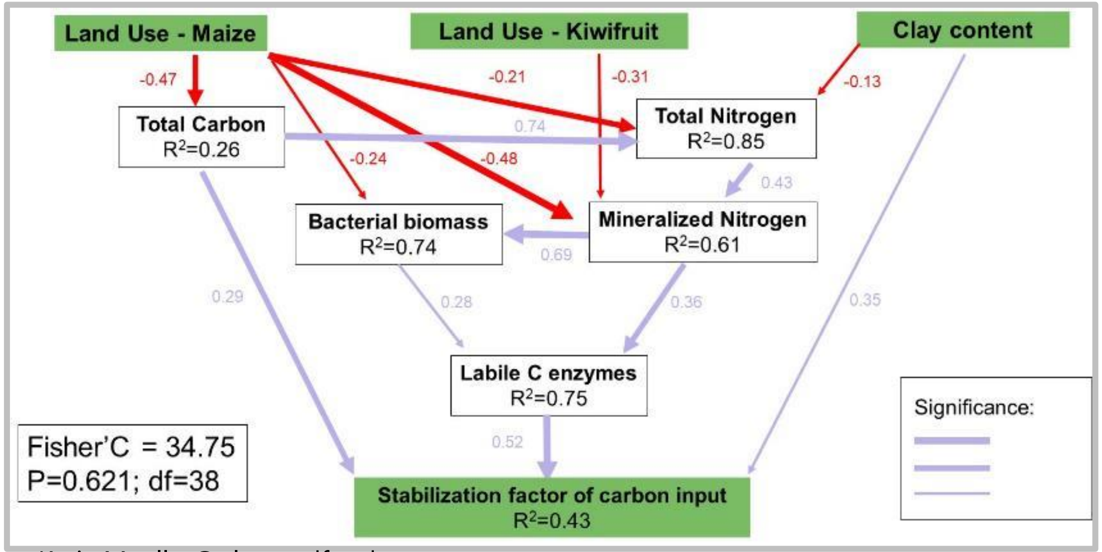
From: Hermans *et al.* (2020)

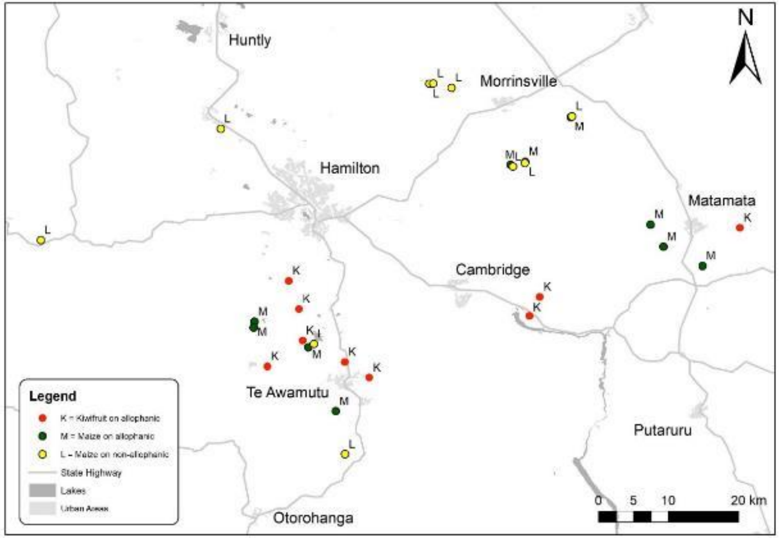
g.lear@auckland.ac.nz

Are carbon decomposition & stabilization influenced by land use?

Manaaki Whenua
Landcare Research

- Teabag index determined in paired-site study (kiwifruit-pasture; maize-pasture) on 2 soils (60 sites)
- Soil quality, microbial & structural indicators, enzyme activities measured upon teabag retrieval
- Random forest analyses identified most influential parameters for both processes
- These were included in structural equation modelling (SEM)
- Preliminary SEM explained 43% and 38% of carbon stabilization and decomposition





Karin.Mueller@plantandfood.co.nz

Other Soil Health MBIE Endeavour (and Associated) Science Outputs:

MINI-REVIEW

Microbial assemblages and bioindicators as proxies for ecosystem health status: potential and limitations

Carmen Astudillo-García[1] · Syrie M. Hermans[1] · Bryan Stevenson[2] · Hannah L. Buckley[3] · Gavin Lear[1]

Received: 18 March 2019 / Revised: 3 June 2019 / Accepted: 4 June 2019

CSIRO PUBLISHING
Soil Research, 2019, **57**, 657–669
https://doi.org/10.1071/SR18210

Effect of long-term irrigation and tillage practices on X-ray CT and gas transport derived pore-network characteristics

Karin Müller[A], Nicola Dal Ferro[B,G], Sheela Katuwal[C], Craig Tregurtha[D], Filippo Zanini[E], Simone Carmignato[E], Lis Wollesen de Jonge[C], Per Moldrup[F], and Francesco Morari[B]

Journal of Applied Ecology
BRITISH ECOLOGICAL SOCIETY

RESEARCH ARTICLE | Full Access

Relationships of plant traits and soil biota to soil functions change as nitrogen fertiliser rates increase in an intensively managed agricultural system

KH Orwin, NWH Mason, L Aalders, N Bell, N Schon, PL Mudge

First published: 26 September 2020 | https://doi.org/10.1111/1365-2664.13771

Soil Chemistry

Decadal Changes in Soil Organic Matter Due to Microaggregate and Hot Water Extractable Pools

Suzanne M. Lambie*
Manaaki Whenua–Landcare Research
Private Bag 3127
Hamilton, New Zealand

Anwar Ghani
AgResearch
Ruakura Research Centre
Private Bag 3123
Hamilton, New Zealand
(current address
29 Birkley Ave, Hillcrest
Hamilton, New Zealand)

Paul L. Mudge
Bryan A. Stevenson
Manaaki Whenua–Landcare Research
Private Bag 3127
Hamilton, New Zealand

Storage of C and N within aggregates is important for long-term stabilization of soil organic matter (SOM). We investigated whether changes in C and N associated with physical soil fractions and the hot water extractable pool were correlated to changes in topsoil C and N over three decades. Archived soil samples from three soil orders collected from 46 sites across New Zealand were physically fractionated and the aggregate abundance (and C and N contents) of fractions determined; hot water extractable C (HWC) and hot water extractable N (HWN) were also measured. Together the change of C and N in hot water extractable SOM, microaggregate within macroaggregate, and free microaggregate fractions explained 60 and 47% of the change in whole soil C and N, respectively. Soil order was not a significant factor in the model suggesting that similar processes were operating in all three soil types. In summary, the development of strategies that enhance the storage of labile SOM and microaggregates could reverse the trend of loss of SOM and its associated ecosystems services.

Abbreviations: NSA, National Soil Archive; SOM, soil organic matter; WHC, hot water extractable carbon; WHN, hot water extractable nitrogen.

BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

Managing soil health for sustainable agriculture

Volume 1: Fundamentals

Soil and soil health: an overview

Mark G. Kibblewhite, Cranfield University, UK and Landcare Research, New Zealand

Hermans et al. *Microbiome* (2020) 8:79
https://doi.org/10.1186/s40168-020-00858-1

Microbiome

RESEARCH Open Access

Using soil bacterial communities to predict physico-chemical variables and soil quality

Syrie M. Hermans[1], Hannah L. Buckley[2], Bradley S. Case[2], Fiona Curran-Cournane[3], Matthew Taylor[4] and Gavin Lear[1*]

Contents lists available at ScienceDirect
Applied Soil Ecology
journal homepage: www.elsevier.com/locate/apsoil

The interactions between biochar and earthworms, and their influence on soil properties and clover growth: A 6-month mesocosm experiment

Stanislav Garbuz[a,*], Marta Camps-Arbestain[a], Alec Mackay[b], Brian DeVantier[b], Maria Minor[a]

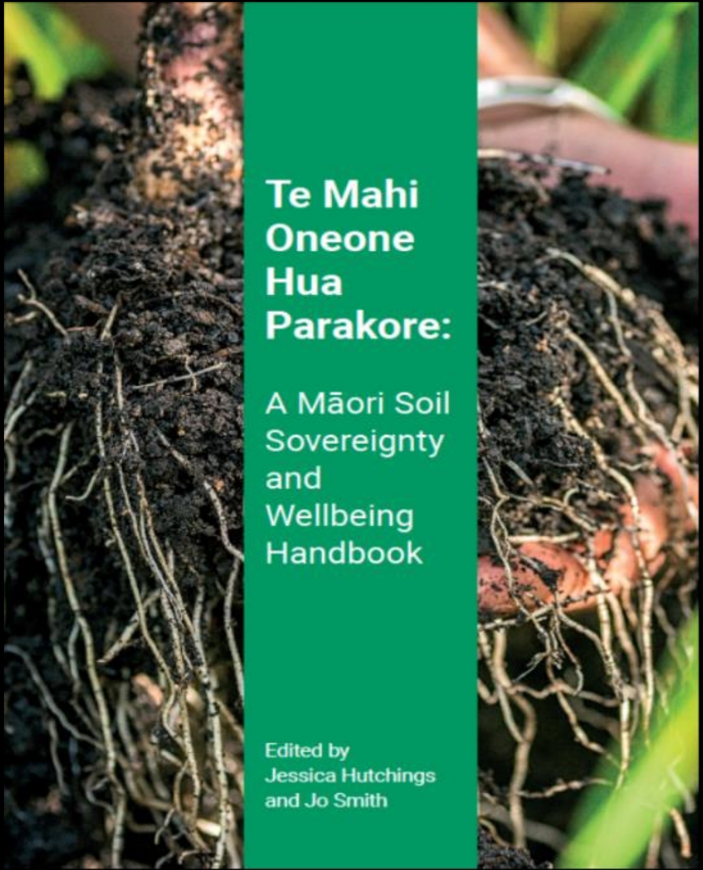
Geoderma 363 (2020) 114134
Contents lists available at ScienceDirect
Geoderma
journal homepage: www.elsevier.com/locate/geoderma

The Land Resource Circle: Supporting land-use decision making with an ecosystem-service-based framework of soil functions

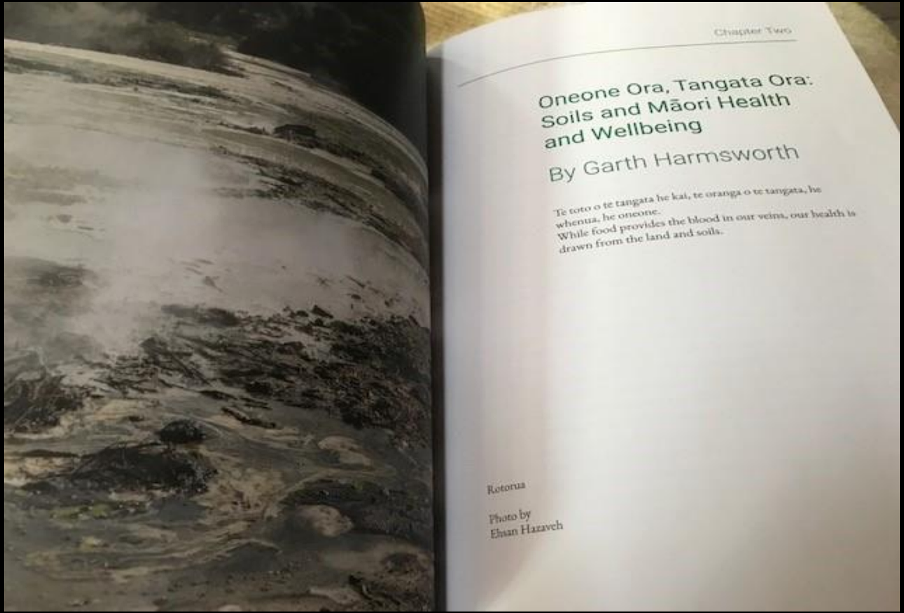
Linda Lilburne[a,*], Andre Eger[a], Paul Mudge[a], Anne-Gaelle Ausseil[a], Bryan Stevenson[a], Alexander Herzig[a], Mike Beare[b]
[a] Manaaki Whenua – Landcare Research, PO Box 69040, Lincoln, Canterbury, New Zealand
[b] Plant & Food Research, Private Bag 4704, Christchurch Mail Centre, Christchurch, New Zealand

stevensonb@landcareresearch.co.nz

Developing Māori views on soil health



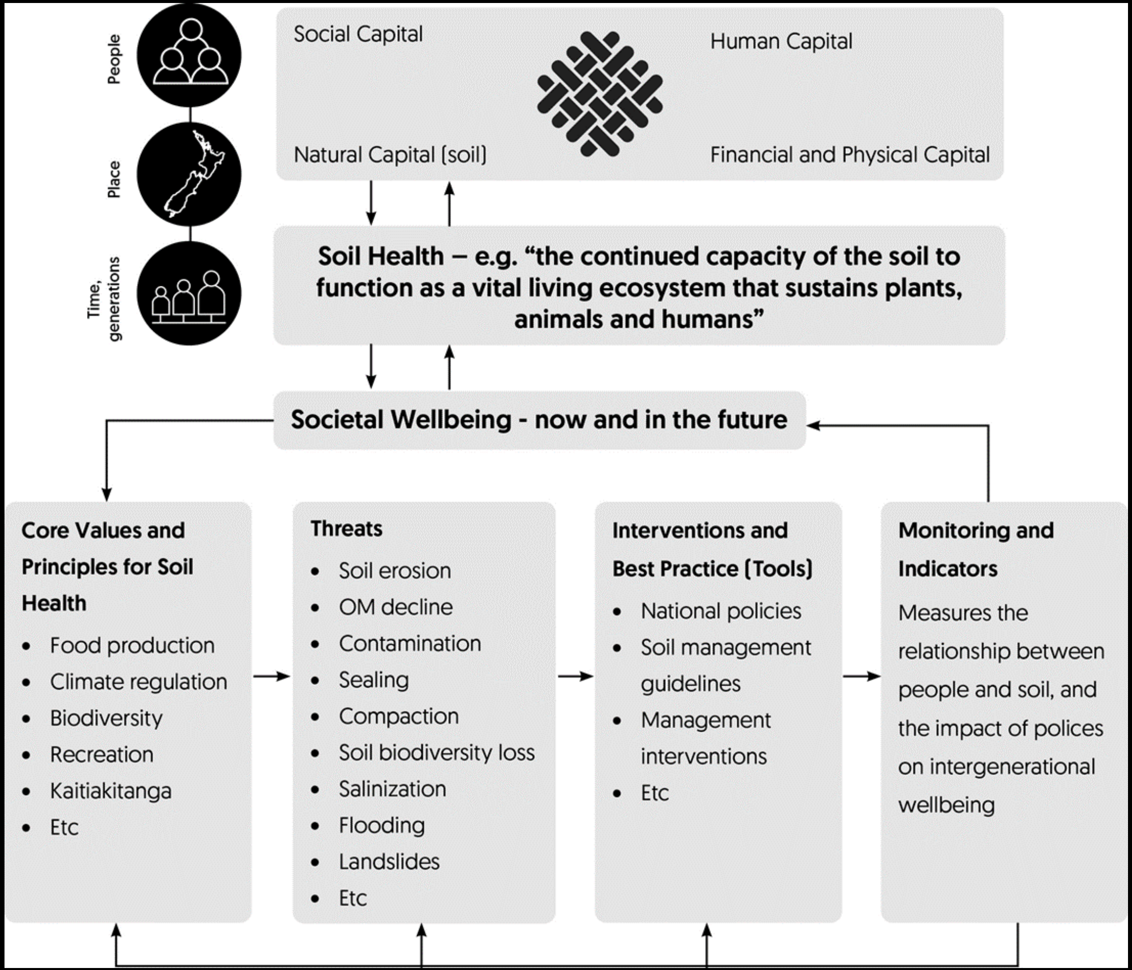
Hutchings J. and Smith J. 2020. Te Mahi Oneone Hua Parakore: A Māori Soil Sovereignty and Wellbeing Handbook. 190p. ISBN 9780473516192. Free Range Press.



kiaora@jessicahutchings.org.nz

harmsworthg@landcareresearch.co.nz

Soil Health and Well-being



(From: Stronge et al. 2020)

stronged@landcareresearch.co.nz

Soil health issues largely boil down to "…societal negotiation in the face of unavoidable trade-offs between various soil uses…"

Bünemann, E.K.; Bongiorno, G.; Bai, Z.; Creamer, R.E.; De Deyn, G.; de Goede, R.; Fleskens, L.; Geissen, V.; Kuyper, T.W.; Mäder, P. Soil quality—A critical review. Soil Biol. Biochem. 2018, 120, 105–125.