

Soil Health in NZ; a personal journey

Matthew Taylor

Whakataukī (Indigenous Māori proverb)

Te toto o te tangata he kai, te oranga o te tangata, he whenua, he oneone

"While food provides the blood in our veins, our health is drawn from the land and soils"

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Introduction

Soil health is not a recent development but stems from the work of the giants on who's shoulders we stand:

By 1911 Bernard Aston had published the first of a long list of studies on the chemistry of bush sickness

"While food provides the blood in our veins, our health is drawn from the land and soils", Indigenous Māori proverb

Roadmap

What is soil quality monitoring?

Soil Quality to Soil Health in NZ

- Beginnings
- Soil Quality research
- SoE monitoring
- Beyond soil quality monitoring

What could Soil Health monitoring look like?

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What is soil quality monitoring?

Measuring how well soil does what we want it to do

- The suitability of soil for its use.
 - No one property can describe soil quality
 - Targets and limits



Need to balance multiple and sometimes conflicting soil uses/services

- e.g. productivity and environmental protection
 - Tradeoffs

Soil quality is connected to biota (especially plants), air, groundwater and surface water quality

Compare: **Soil health is the condition of the soil and whether the soil has been degraded, i.e. the multifunctional capacity of the soil system to deliver all its functions**

Context: why we have soil quality monitoring in NZ

Need for evidence for State of the Environment National reporting

- Evaluating the effectiveness of planning and implementation
- Environmental protection

Need to provide early warning of emerging issues and contamination

Overseas (USA, Ireland).

Providing for sustainable agronomic intensification and promotion of socio-economic well-being.

“sustainable intensification”

- increases in outputs
- finite inputs

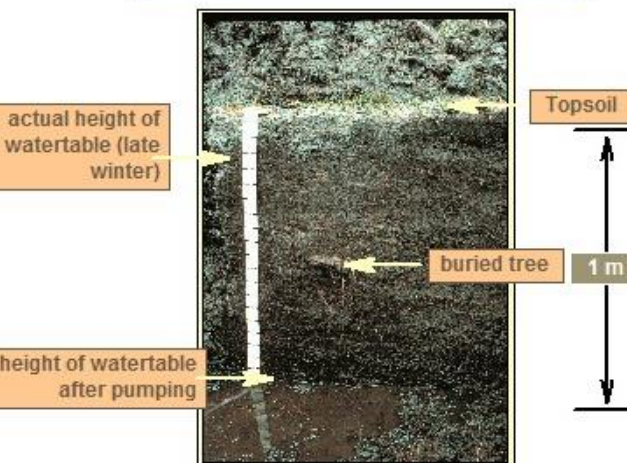
Inherent and dynamic soil properties



- Inherent soil quality properties are not feasible for human change
- Give the suitability of a soil for a particular purpose



Peat soil from the Rukuhia swamp,
just south of Hamilton



Dynamic factors

Note interactions between factors

- Compaction
- Excessive nutrients
- Loss of soil organic matter
- Soil acidity
- Stability/erosion
- Contamination
- Biological activity



My soil health journey: Start

- 1st year science and health technology were combined
 - Applied focus
- Soil Bureau survey work



Soil Quality research – DSIR Soil Bureau/Manaaki Whenua Landcare Research

- Problem: There was a lack of nationally consistent or scientifically based soil quality monitoring data for New Zealand
- Initial conversations and development of the concept by Graham Sparling and Louis Schipper ~ 1994
- First field samples in 1995



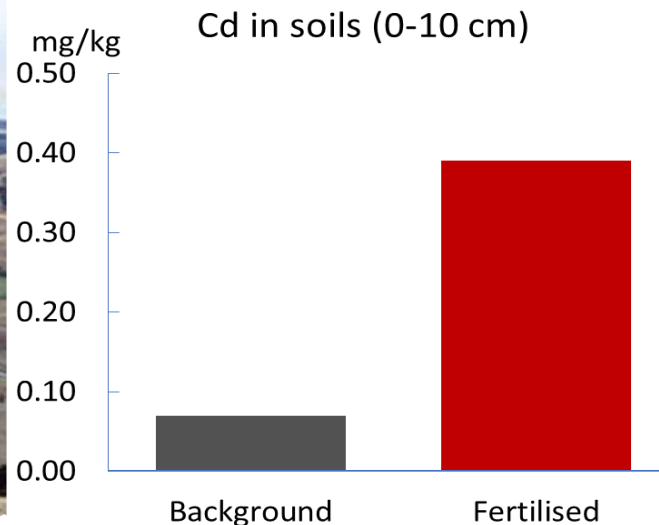
Research and transition to RC phases

1. Sustainable Management Fund Research Projects

- a) 5001, Trialling Soil Quality Indicators for State of the Environment Monitoring (1997/98)
- b) 5089, Implementing Soil Quality Indicators for Land (1998-2001).

2. Concurrently, devolution of environmental management from central to regional government

- a) Required to report on the State of the Environment



A screenshot of the Waikato Regional Council website. The page displays a report titled "Implementing soil quality indicators for land: Waikato region 2003-2004" (TR 2004/14). The report is authored by Graham Sparling, Landcare Research. The abstract states that the report is part of the Annual Plan, detailing regular sampling to assess soil quality in the region. It mentions that there are now some 80 identified and characterised sites throughout the region, providing a 'snapshot' of soil quality. The report also notes that the strategy for sampling in 2003/2004 was to revisit a subset of characterised sites to determine what changes in soil quality characteristics had occurred since the initial sampling. The rates and direction of changes in soil quality properties are useful to determine which land managements are sustainable in the longer term, and whether undesirable trends are emerging. Pastoral land uses dominate in the region and this land use was targeted for resampling. Soil quality on the sites was appraised using a set of soil chemical, physical and biological indicators tested in the 500 Soils Project (Mill et al. 2003). A link to the PDF report is provided: "Implementing Soil Quality Indicators for Land - Waikato Region 2003-2004 (PDF, 269 KB)". The website footer includes the Waikato Regional Council logo, contact information (0800 500 401), and a list of popular pages such as "Pay my rates", "Find my rates", "Rise levels and rainfall", and "More".



NEW ZEALAND



CHATHAM IS. TERRITORY

Waitangi

CHATHAM IS.

PITT IS.

Tasman Sea

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*SOUTH
PACIFIC
OCEAN*

NORTHLAND
Whangarei

NORTH ISLAND

AUCKLAND
Auckland

Hamilton
Tauranga

WAIKATO

BAY OF PLENTY

GISBORNE

Gisborne

New Plymouth

TARANAKI

HAWKE'S BAY
Napier

WANGANUI-MANAWATU

Palmerston North

NELSON

WELLINGTON

Wellington

Richmond
TASMAN
MARLBOROUGH

Blenheim

Greymouth

WEST COAST

Christchurch

CANTERBURY

OTAGO

SOUTHLAND

Dunedin

Invercargill

STEWART IS.



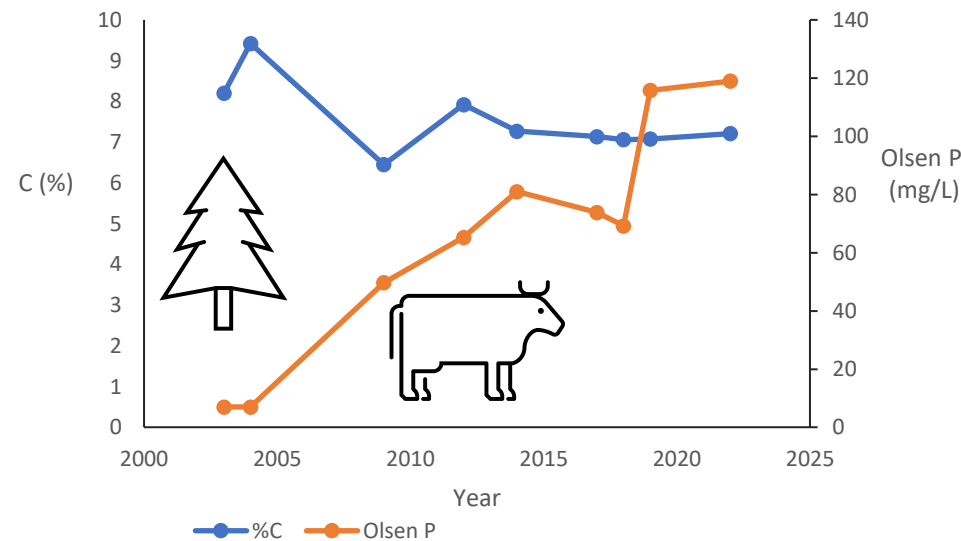
From research programme to monitoring programme

1. Regional Council's need to monitor
2. **The Land Monitoring Forum**
 - a) National body of regional council soil and land scientists
 - b) To coordinate and enable consistency across regions
 - i. Initial manual
 - ii. Reviews of target ranges
 - iii. Contribute to the National Environmental Standard (soil quality)
 - iv. Further development



Land and Soil Monitoring: A guide for soil and regional council reporting

LAND MONITORING FORUM



How is soil quality currently assessed in NZ

- New NEMS – Consistent Methods, how we do it
- Seven soil characteristics are measured: total carbon, total nitrogen, mineralisable nitrogen, acidity, plant-available phosphorus, bulk density and macroporosity.
- As, Cd, Cr, Cu, Pb, Ni, Zn and total F are also specified in the NEMS
- Assessed under various land uses, e.g. native, forestry, cropping, horticulture, pasture.
 - Targets for each land use



National Environmental Monitoring Standard

Soil Quality and Trace Elements

Sampling, Measuring, and Managing Soil Quality and Trace Element Data

Version 1.0.0

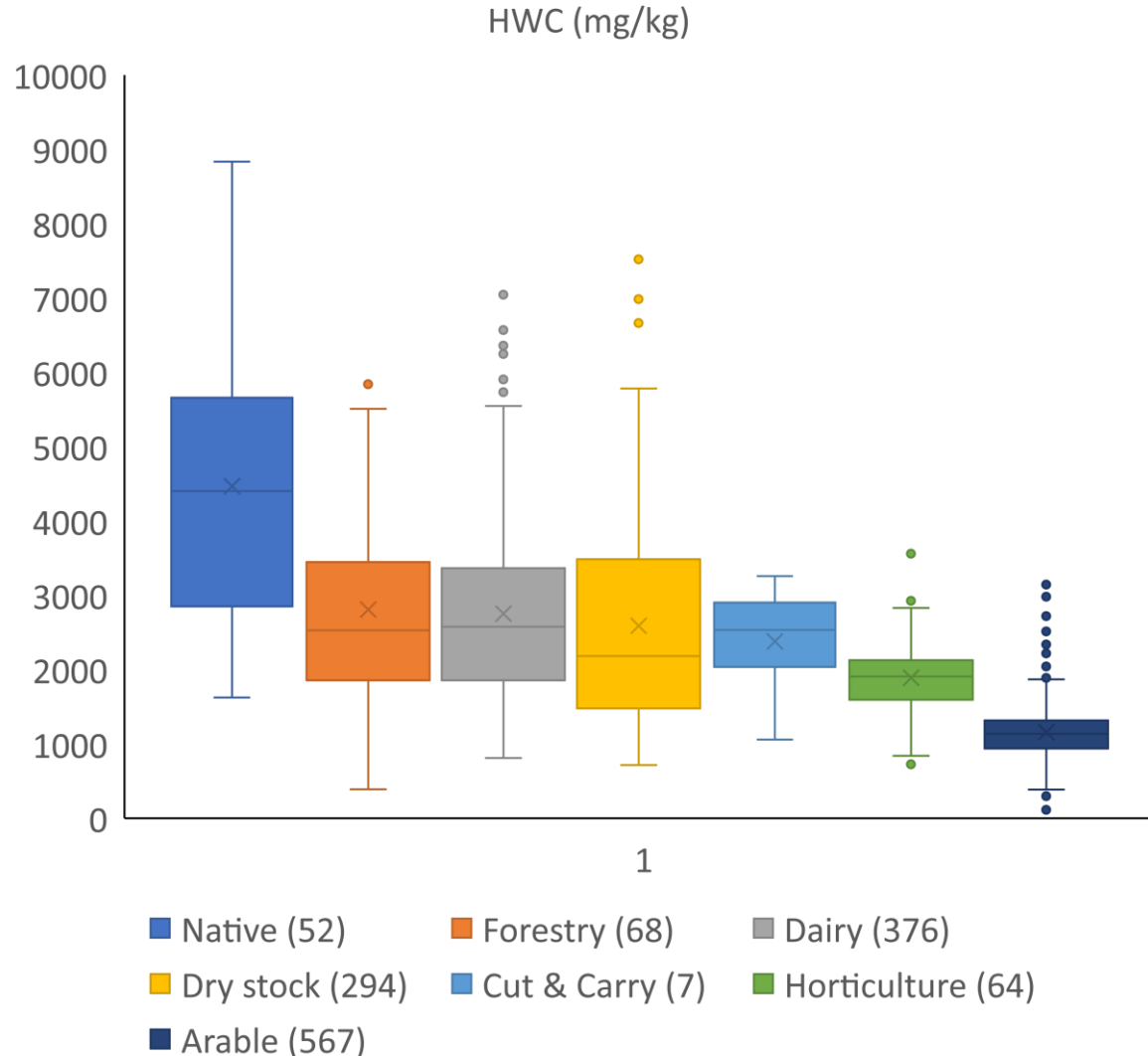
Date of Issue: July 2022



Soil State of the Environment reporting

1. There is a balance between soil functions for productivity, environmental quality, plant and animal health, etc.
 - a) Monitoring variables need to
 - i. Be a measurable property.
 - ii. Respond to change in a soil function, service or process.
 - iii. Be stable enough for change to be associated with a specific soil function, service or process but responsive enough to show change within a manageable period.
 - iv. Have definition of what is “good”.
2. Soils with good soil quality (or soil health) have strong resilience to external pressures.
3. No one property alone can describe a soil’s state.
4. Issue for a democracy, access to private property.

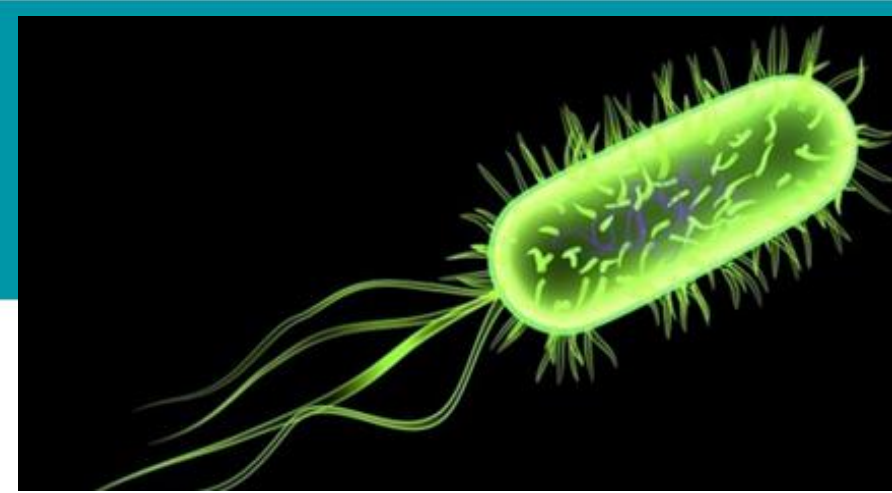
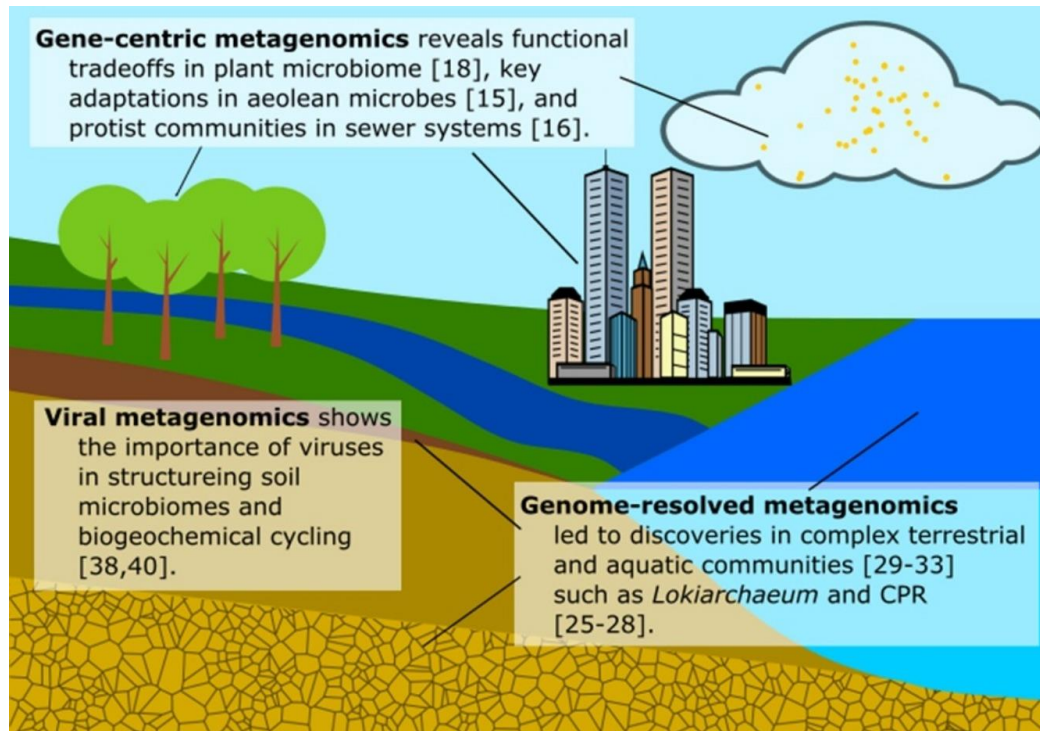
Beyond “soil quality monitoring”: Adding new variables



Hot water extractable C and N

- HWC is an integrated measure of soil biochemical quality.
- HWN as a measure of mineralisable N
- LMF have provisional targets

- eDNA
 - Microbial community and genomics assessment
- Earthworms



Taş, N., de Jong, A.E., Li, Y., Trubl, G., Xue, Y. and Dove, N.C., 2021. Metagenomic tools in microbial ecology research. *Current Opinion in Biotechnology*, 67, pp.184-191.

Louissou, Z., Hermans, S.M., Buckley, H.L., Case, B.S., Taylor, M., Curran-Cournane, F. and Lear, G., 2023. Land use modification causes slow, but predictable, change in soil microbial community composition and functional potential. *Environmental Microbiome*, 18(1), pp.1-16.

Hermans, S.M., Buckley, H.L., Case, B.S., Curran-Cournane, F., Taylor, M. and Lear, G. 2020 Using soil bacterial communities to predict physico-chemical variables and soil quality. *Microbiome* 8:79

Hermans, S.M., Taylor, M., Grelet, G., Curran-Cournane, F., Buckley, H.L., Handley, K.M., Lear, G. 2020. From pine to pasture: land use history has long-term impacts on soil bacterial community composition and functional potential. *FEMS Microbiology Ecology* 96, fiae041, 1-12.

Hermans, S.M., Buckley, H.L., Case, B.S., Curran-Cournane, F., Taylor, M. and Lear, G. 2017. Bacteria as emerging indicators of soil condition. *Applied and Environmental Microbiology*, 83(1), pp.e02826-16.

Soil bacterial communities are affected by soil pH and phosphorous concentrations

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Introduction

Bacteria are involved in key soil biogeochemical cycles¹, interact with plants to affect their growth^{2,3} and even effect the structure of soil^{4,5}.

However, despite their importance to soil ecosystem health and production potential, we know little of the response of bacterial communities to anthropogenic activity.

Agricultural and horticultural land covers almost 42% of the country and exotic forests cover ~7.5%⁶. It is therefore desirable to determine how productive land use impacts the bacterial communities living in these soils.

Methods

We sampled soil from 110 sites in the Auckland and Waikato regions, classified as belonging to dairy, dry stock, horticulture, exotic forest or indigenous forest land uses (Fig 1).



Figure 1. Location of indigenous forest (green), exotic forest (purple), horticulture (blue), dairy (red) and dry stock (yellow) sites sampled within the Auckland and Waikato regions.

We collected a wide range of soil chemical and physical data as well as climate data for each site.

DNA was extracted from every soil sample. Bacterial taxonomic composition was assessed by amplifying and sequencing bacterial 16S rRNA gene regions.

The site metadata and bacterial data was then used in subsequent statistical analyses to determine the relationships between land use, site characteristics and bacterial communities.

Results

Different land uses harboured different bacterial communities, with the clearest difference between the indigenous samples and the four human impacted land uses (Fig 2).

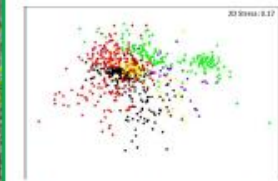


Figure 2. The underlying differences in bacterial community composition (beta-diversity) of all the samples (grey) superimposed on a non-metric MDS plot. Samples are colored according to the land use: indigenous forest (green), exotic forest (purple), horticulture (blue), dairy (red), and dry stock (yellow).

The core microbiomes for the human impacted environments (dairy, dry stock, horticulture and exotic forest sites) are relatively similar to each other in composition, while the core microbiome for the indigenous forests was most different from the others (Fig 3).

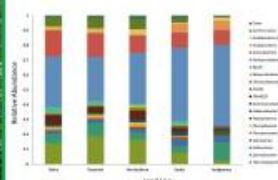


Figure 3. The relative abundance of bacterial classes that make up the core microbiomes for each land use. Each color represents a different bacterial class. The x-axis shows land use categories: Dairy, Dry Stock, Horticulture, Exotic Forest, and Indigenous Forest. The y-axis shows relative abundance from 0 to 100.

Fig 4 shows that bacterial communities under managed land uses differ from their natural counterparts, with the two most intensive land uses, horticulture and dairy, harbouring communities that are the least similar to those found in indigenous forests.

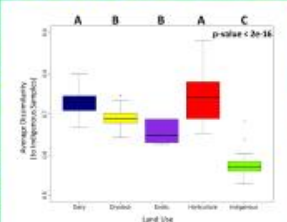


Figure 4. The dissimilarity of the bacterial communities found within each land use compared to the communities found in indigenous forest soils. The value from the ANOVA is given in the top right hand corner. Land uses not treated by the same letter are significantly different from each other (Tukey's p-value < 0.05).

Differences in bacterial community composition under managed land uses, as compared to indigenous forests, were most closely correlated to differences in Olsen P concentration (Fig 5).

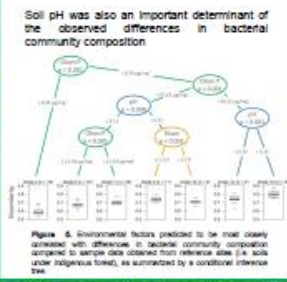


Figure 5. Soil pH was also an important determinant of the observed differences in bacterial community composition. The relationship between soil pH and Olsen P concentration is shown. The regression line is shown for the indigenous forest data points.

Conclusions

Bacterial communities in soils from different land uses differ in their composition.

There is a link between land use intensity and the extent that bacterial communities differ to those in indigenous forest soils.

Olsen P was identified as a critical variable, associated with observed differences in bacterial community composition across land uses.

1. Peoples, P.M., & Naylor, R. (2005). Modelling complex land use systems using a multi-scale, multi-scale, multi-scale approach to soil evaluation. *Soil Science Society of America* 69: 1077-1077.
2. Gough, S., & Naylor, R. (2005). The use of soil quality indicators for the assessment of soil health. *Proceedings of the 1st International Conference on Soil Quality Indicators*, 1-10.
3. Gough, S., & Naylor, R. (2005). The use of soil quality indicators for the assessment of soil health. *Proceedings of the 1st International Conference on Soil Quality Indicators*, 1-10.
4. Gough, S., & Naylor, R. (2005). The use of soil quality indicators for the assessment of soil health. *Proceedings of the 1st International Conference on Soil Quality Indicators*, 1-10.
5. Gough, S., & Naylor, R. (2005). The use of soil quality indicators for the assessment of soil health. *Proceedings of the 1st International Conference on Soil Quality Indicators*, 1-10.

Beyond “soil quality monitoring”: Current research

- Pesticide Residue Research
 - Auckland University/Plant & Food Research
- Emerging Contaminants Research
 - Microplastics
 - Antimicrobial resistance
- Erionite (similar props to asbestos)



Beyond “soil quality monitoring”: Other monitoring

- Soil stability and erosion
 - Riparian survey



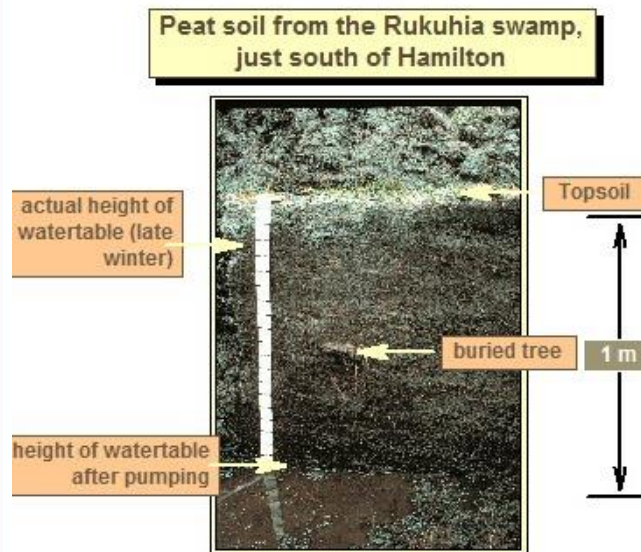
This map shows the areas that have a low, moderate and high potential for erosion in the Waikato region.





Beyond “soil quality monitoring”: Other monitoring

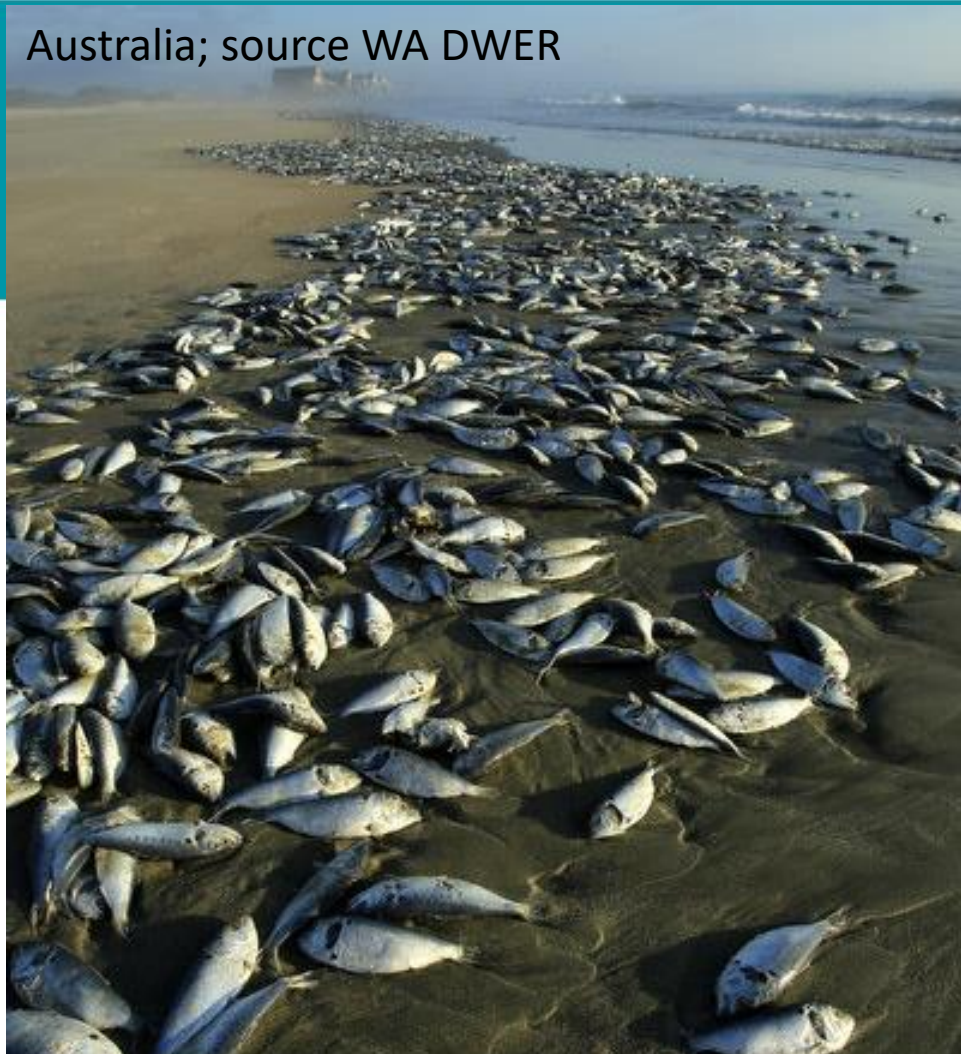
- Carbon and Green House Gas
 - GHG regional inventory
 - Organic soils
 - Current extent
 - Quality
 - Waikato peatlands cover approximately 94,000 hectares and contain about 2,700 million cubic metres of peat.



Beyond “soil quality monitoring”: ASS

- Soil acidity
 - Not topsoils
 - Acid sulphate soils
 - Marine sediments
 - Buried ~ 2 m down

Australian Acid
sulphate soil
(source WA DWER)



Australia; source WA DWER



Soil Health Research: Current

1. **Manaaki Whenua Landcare Research project 'Soil health and resilience: oneone ora, tangata ora',**
 - a) To support the development of a longer-term and more comprehensive view of soil health and resilience; and to develop an integrated soil health framework that can be used by a wide range of end-users.
 - b) The ongoing capacity of soil ecosystems to maintain the services they provide is fundamental to our well-being.

What will Soil Health monitoring look like?



- A relative rating that depends on the suitability of the soil for its actual use only.
- Deviation from an ideal soil with ideal properties.

However, soil health depends on who the health is for!

Soil health from different points of view:

Specialised organisms

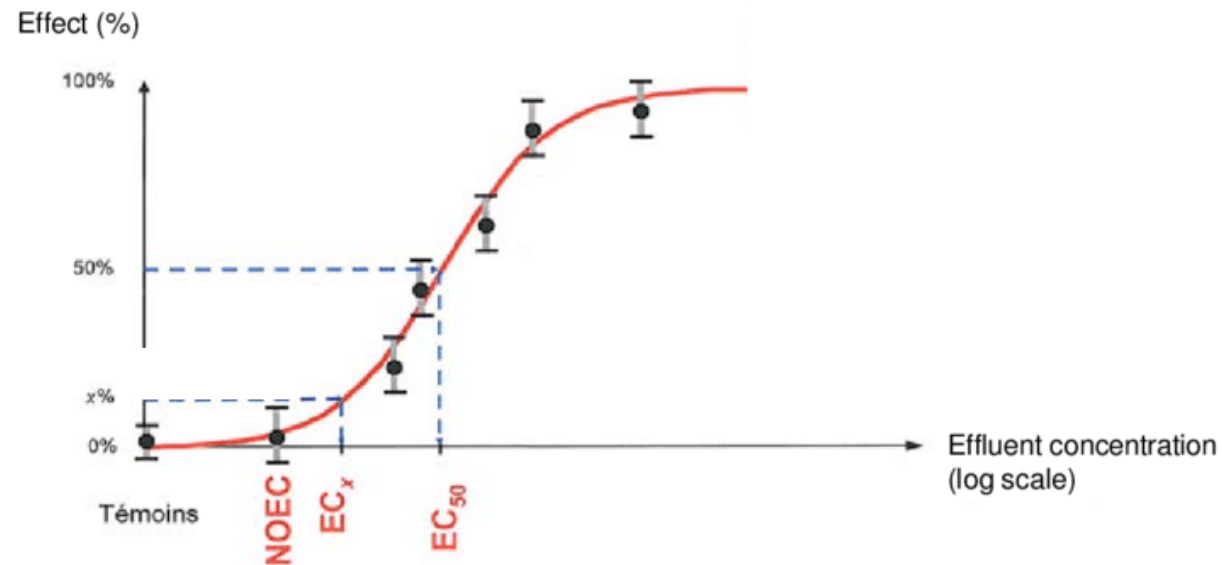
- Only grow in specialised environments
- Low level of biodiversity



Soil health from different points of view:

General ecology

- Most soil and organisms can thrive
- Biodiversity



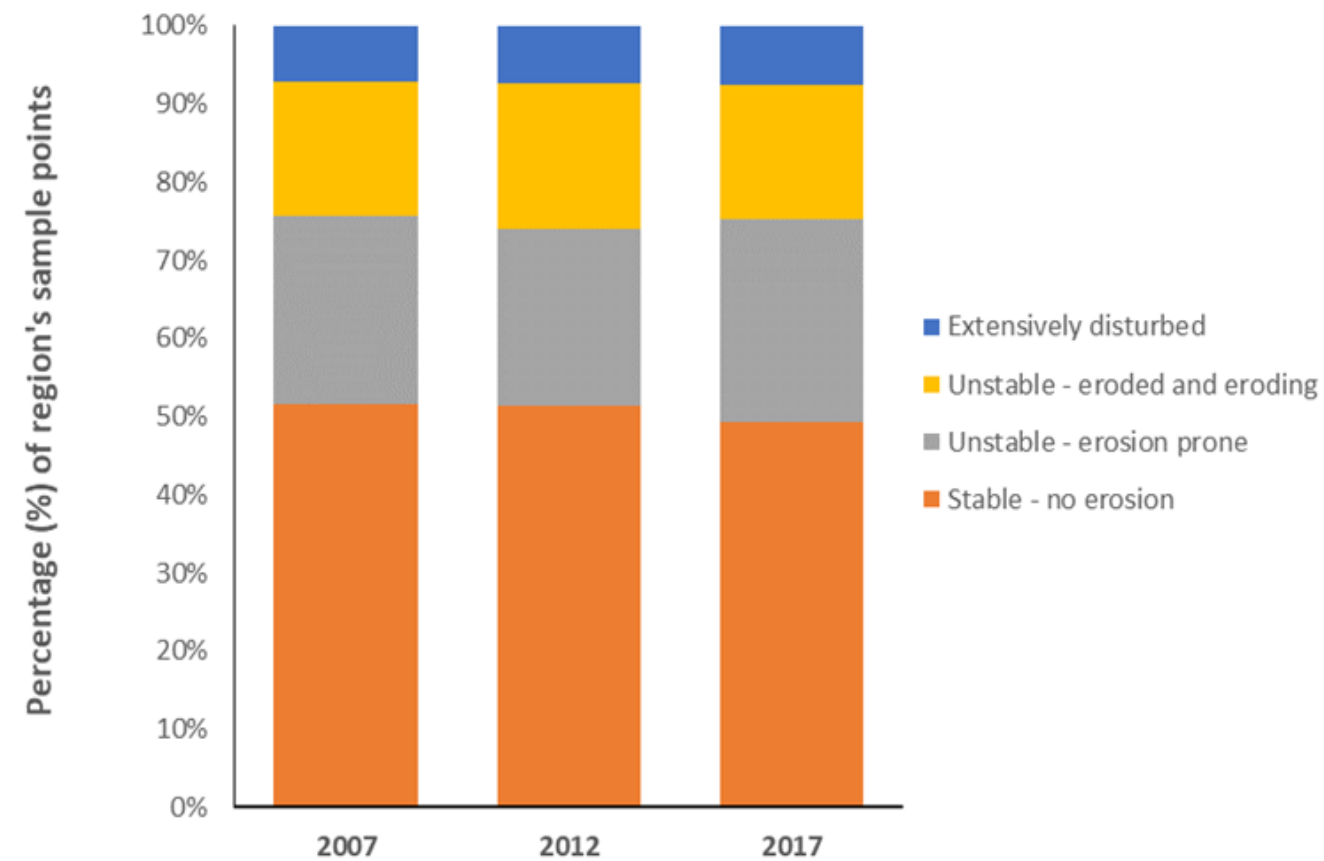
Soil health from different points of view:

Production
(and air health)



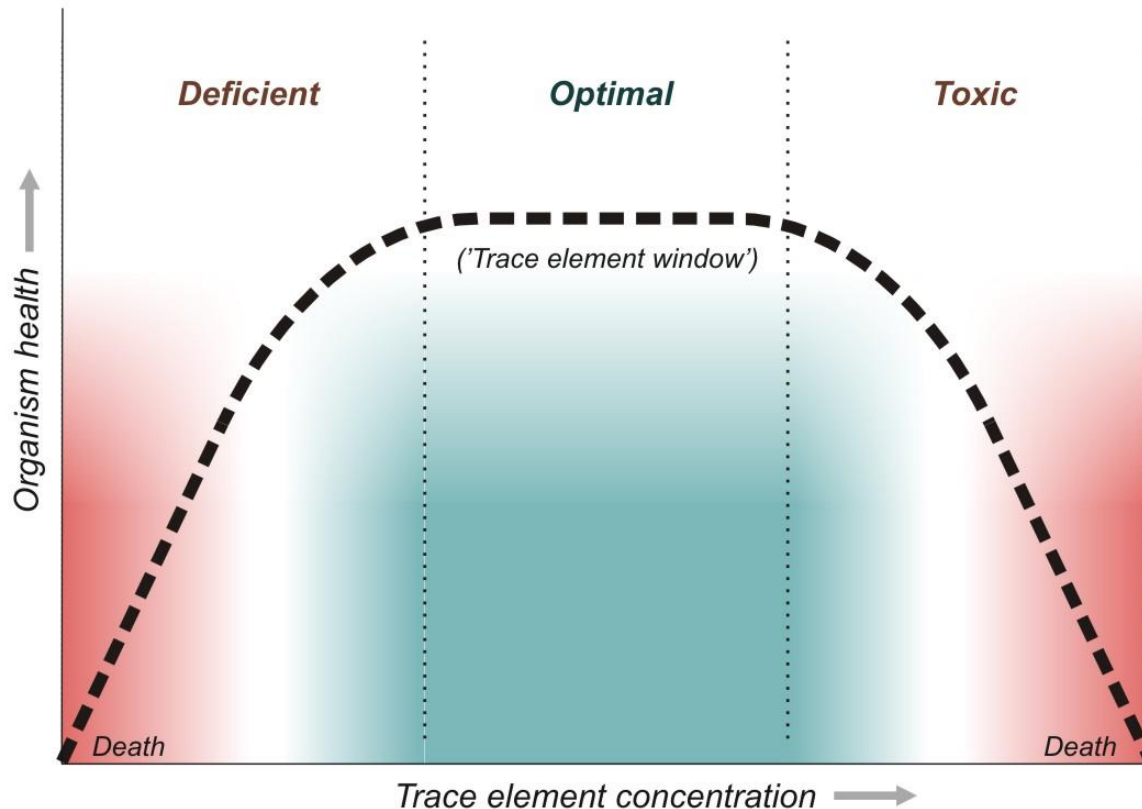
Soil health from different points of view:

Stability



Soil health from different points of view:

Nutrient management



Soil health from different points of view:

Water Quality

Contaminant treatment



Soil health from different points of view:

Structure



Soil health from different points of view:

SOM
GHG



Soil health from different points of view:

Contamination

- Loss of production
- Loss of biodiversity





Geothermal soil

How to consider ash from active volcanoes?





Earthquake

Climate change

Growing bananas in New Zealand's South Island
and 4 banana varieties to try



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Considerations for Soil Health monitoring

All is connected

- a) Soil health impacts biology, water and air health
- b) First nations and other native people have useful perspectives
 - i. "Indigenous Māori perspectives of soil (oneone) and soil health incorporate the indivisible connection between the wider environment (taiao), ecosystems, and human health" - Garth Harmsworth.
 - ii. There is an ancestral lineage that links humans to all other organisms (down to microbes), through an intricate hierarchical web.
 - iii. Long-term and multigenerational
 - iv. All environmental domains are connected and related personalities



Soil Health monitoring: what we need

A balance between soil functions for productivity, environmental quality, and plant and animal health (including microorganisms)

- Multiple variables to allow assessment for different needs and viewpoints
- Monitoring variables need to
 - i. Be a measurable property
 - ii. Respond to change in a soil function, service or process.
 - iii. Be stable enough for change to be associated with a specific soil function, service or process but responsive enough to show change within a manageable period.

Physical indicators could include:

- soil bulk density
- macroporosity (which relate to compaction)
- soil aggregates which help to determine soil structure

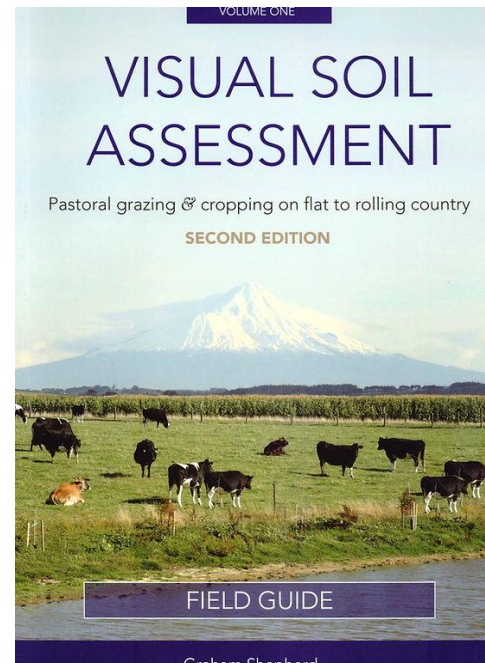
Chemical indicators could include:

- pH,
- nutrients/fertility
- trace elements and pollutants

Organic matter and biological indicators could include:

- total organic carbon (C) and nitrogen (N),
- mineralizable nitrogen (as a surrogate for microbial biomass)
- measures of labile or soluble carbon and nitrogen (such as hot-water extractable C and N).
- abundance and diversity of microbes and other soil biota such as worms (difficult to measure, variable over time or difficult to interpret)
- soil food web interactions
- pests and undesirable biota

Visual Soil Assessment



waikatoregion.govt.nz





How many soil scientists does it take to auger a hole?

Thanks