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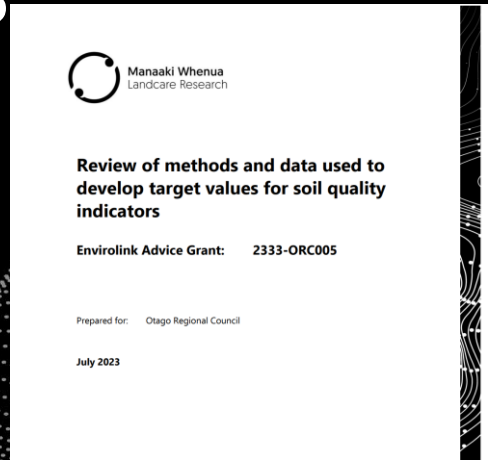
Manaaki Whenua
Landcare Research

MANAAKI WHENUA – LANDCARE RESEARCH

Revision of soil quality indicators target ranges

Ministry for the Environment
Manatū Mō Te Taiao


Manaaki Whenua
Landcare Research

Review of methods and data used to develop target values for soil quality indicators

Envirolink Advice Grant: **2333-ORC005**

Prepared for: Otago Regional Council

July 2023

Project team

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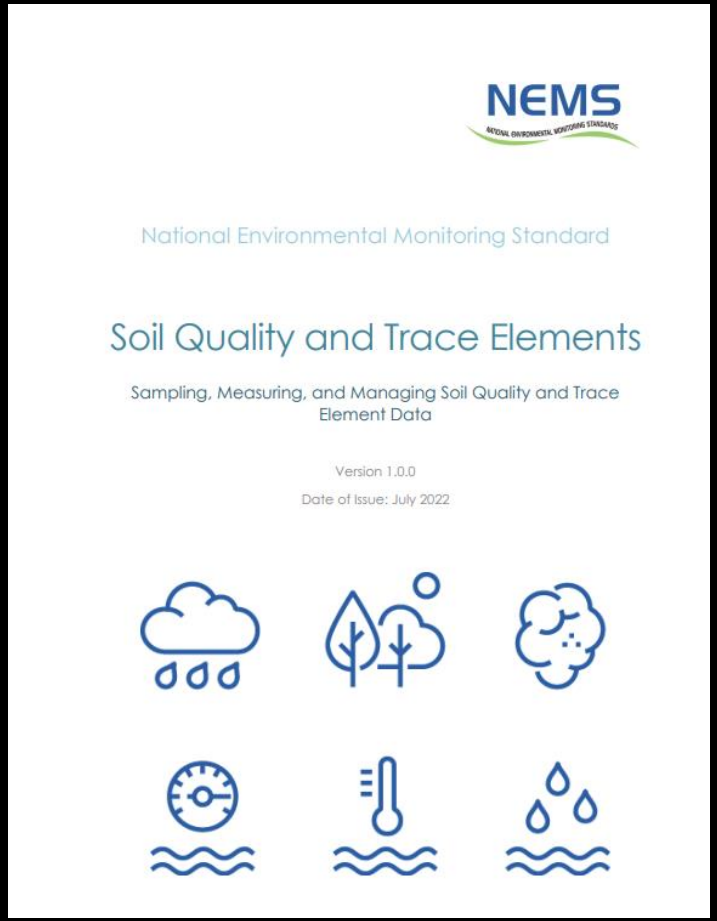
SCION — Loretta Garrett, Chandra Ghimire, Peter Clinton



Project objectives

- Revise and propose new target ranges for soil quality indicators by considering new research and data generated since soil quality monitoring started, providing greater insight on environmental responses to factors measured by soil quality indicators.

- [Provide transparency on the basis & interpretation of the target ranges]

- Indicators covered:
  - pH, **total C**, total N, anaerobically mineralisable nitrogen, **Olsen P**, **macroporosity**, bulk density
  - hot-water extractable carbon

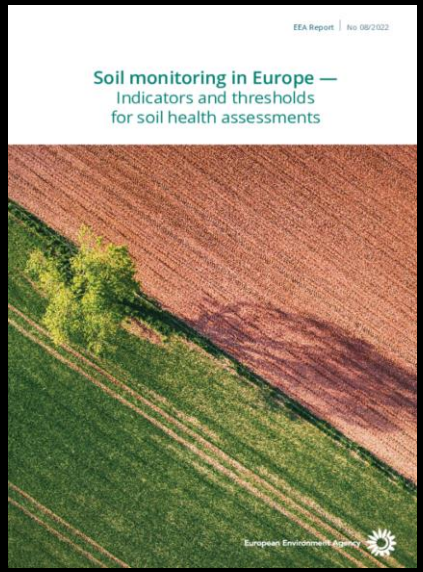
Indicator	Description	Production	Environment
pH	Soil acidity	Optimal range	
Total C	Indicator of organic matter	Yield impacts at low C	Biological activity Soil structure
Total N	Organic matter N	Insufficient N can limit yield	Water quality impacts
AMN	Labile organic matter N, biological activity	N-supply	Water quality Biological activity
Olsen P	Available P	Insufficient P can limit yield	Water quality impacts
Macroporosity	Soil aeration and compaction	Affects yield	Surface run-off, infiltration
Bulk density	Compaction		
HWEC	Labile carbon, biological activity	Nutrient supply	Biological activity

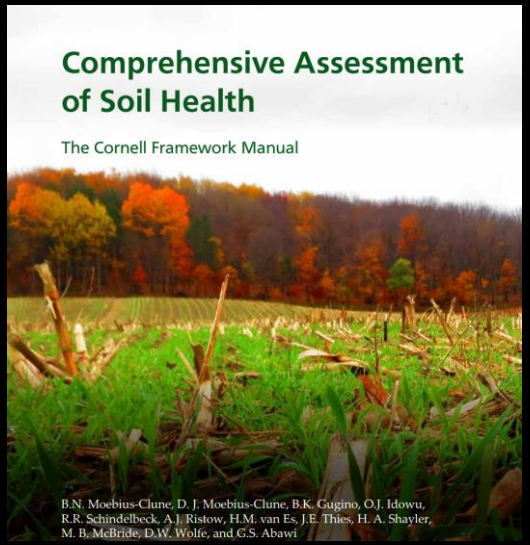
Project overview

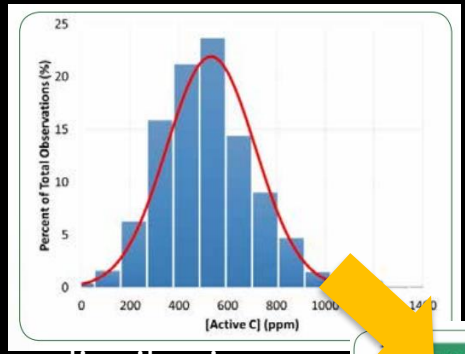
- Targeted literature review (national and international)
- Workshop (August 2024)
  - Scoping broader use of numeric criteria, data availability
- Data analysis to develop revised numeric criteria
  - Olsen P conversion – gravimetric/volumetric
- Workshop 2 (November 2024)
  - Presentation of potential revised target values for discussion
- Revised numeric criteria & areas for future focus
  - Interpretation
- Draft report (24 April 2025)
- Final report (31 May 2025)

Project overview

- Targeted literature review
  - National, specific focus on identifying published studies or datasets
  - International, focus on development of targets/thresholds

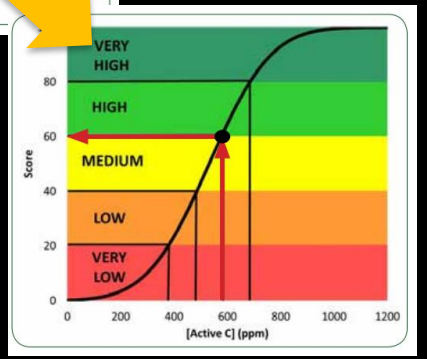






distribution

score



Data analysis

- NZ data overview
  - Limited studies linking soil quality to environmental outcomes
    - Most extensive: Olsen P in overland and sub-surface flow
    - Fluxmeter studies of cropping soils
  - Multiple extensive datasets provide data on ‘state’
    - Regional councils SOE collation for Our land 2021* (7 indicators)
    - Additional regional council data* (GDC, ORC, HWEC)
    - National Soil Carbon Monitoring programme* (5 indicators)
    - Environment Canterbury Arable and Pastoral monitoring
    - SLURI, LMI, long term trials
    - S-Map (pH, bulk density)
    - Forestry trials (e.g. F380* - 6 indicators)
    - LUCAS (native forest, planted forest plots) (3 indicators)
  - Variable parameters covered,
    - Most data for pH, total C, total N
    - Least data for HWEC, AMN

* Form the baseline monitoring dataset

Revised criteria - Terminology change

- '**Reference range**' rather than '**Target range**'
  - as these values are a range of values that are being referred to provide context for individual results
  - not necessarily a robust basis for values to 'aim' for (Target)

- The interpretation of falling 'outside' the reference range can vary, depending on basis for reference range

- Revision of the numeric ranges was based on an evaluation of existing data, and the 'logic' for interpretation of differing values of the indicator

Basis for reference ranges for individual indicators

- **Fixed** – Static value based on best available research/ knowledge, stratified as required (*pH, Olsen P, minimum C% for cropping soils*)

- **Reference** – Static value, calculated as a percentage of what would be found in a ***reference situation***, where soil processes are occurring in a way that is considered to be desirable, stratified as required (*macroporosity, bulk density*)

- **Distribution** – Based on the national/regional state of the soil (i.e., target/threshold defined as a certain percentile of the current observed range of values)
    - propose this as a ***static value*** using the ***baseline monitoring dataset***

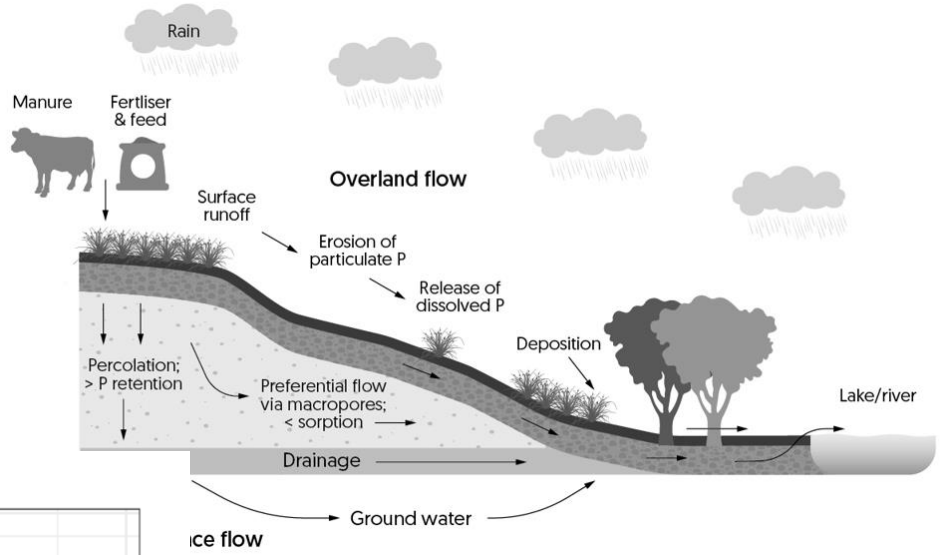
Soil quality indicator	Approach used	Basis of value for different land uses
pH	Fixed	Agronomic recommendations, stratified by land use (agriculture and forestry)
	Distribution	Baseline monitoring dataset for urban and indigenous
Olsen P	Fixed	Agronomic recommendations, stratified by land use and soil 'type'
	Distribution	Baseline monitoring dataset for urban and indigenous
Total C	Fixed	Threshold of 2%C for non-Allophanic mineral cropping soils
	Distribution	Baseline monitoring dataset, stratified by land use and soil type
Total N (C:N)	Distribution	Baseline monitoring dataset, stratified by land use and soil type
AMN	Distribution	Baseline monitoring dataset, stratified by land use and soil type
HWEC	Distribution	Baseline monitoring dataset, stratified by land use
Macroporosity	Reference	Non-treaded and undisturbed forestry dataset
Bulk density	Reference	Non-treaded and undisturbed forestry dataset

Olsen P

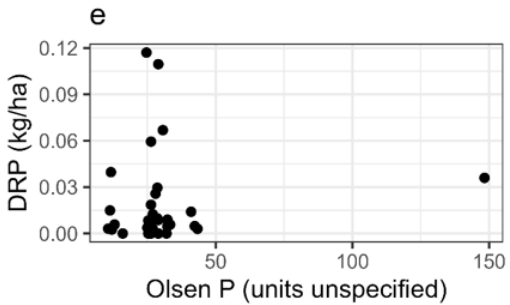
- Based on agronomic recommendations
- Too many factors influence loss of P to waterways for this to be the primary driver for setting Olsen P criteria

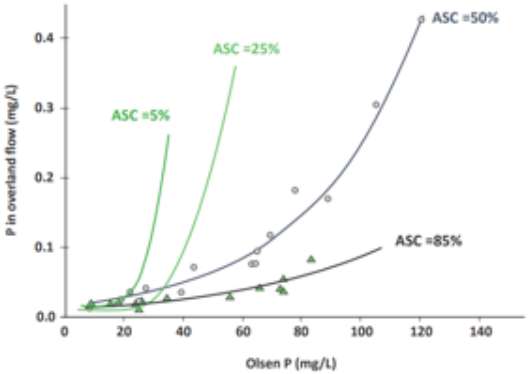
Factors influencing water quality

Factors influencing **leaching**
- Rainfall
- Infiltration
- Porosity
- Connectivity
- P-retention (ASC)



Adapted from McDowell et al 2004





Factors influencing P **surface run-off – paddock scale**
- Sorbed-P/dissolved-P dynamic
- ASC
- Initial soil water content
- Ground cover
- Soil loss fx(Rainfall (amount, timing), slope, grazing regime/cultivation regime

Catchment scale factors
- Area under different land-use

Olsen P

- Based on agronomic recommendations
- Too many factors influence loss of P to waterways for this to be the primary driver for setting Olsen P criteria

Land use group	Soil group	Agronomic recommendations (mg/l)	Agronomic recommendations (mg/kg)
Arable cropping & Orchards	All	10-30	–
Vegetable cropping	All	10-60	–
Vineyard	All	NA	–
Pastoral	Sedimentary, ash	20-30	–
Pastoral	Pumice, peat	35-45	–
Exotic Forestry	All	NA	<25
Indigenous Vegetation	All	Na	Na
Urban	All	<20[2]	–

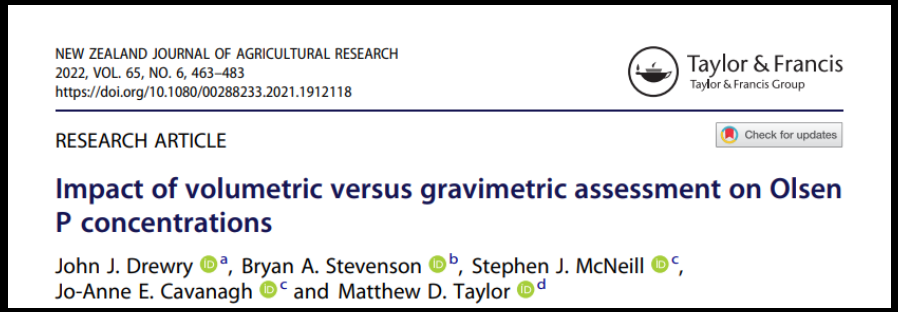
Olsen P – complications….

Volumetric (mg/L)

- A known volume "scoop" is analysed
- Can be converted to gravimetric using lab-measured volume weight
- Production responses measured against volumetric measures

Gravimetric (mg/kg)

- A known mass of soil is analysed
- Some research studies use gravimetric values
- NEMS specifies gravimetric values



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2022, VOL. 65, NO. 6, 463–483
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RESEARCH ARTICLE

Check for updates

Impact of volumetric versus gravimetric assessment on Olsen P concentrations

John J. Drewry [a], Bryan A. Stevenson [b], Stephen J. McNeill [c], Jo-Anne E. Cavanagh [c] and Matthew D. Taylor [d]

- Agronomic recommendations converted to gravimetric values using Drewry et al 2022, and depth-adjustment for pastoral soils
- Cropping soils assumed to be well mixed for top 15 cm, so no adjustment

Gravimetric Olsen P reference ranges

Land use category	Reference range Olsen P[1] (mg/kg)				
	Pumice	Organic, Podzol	Recent, Granular	All others	Raw*
Arable cropping & Orchards	15-57	15-45	10-30	10-35	10-40
Vegetable cropping	15-115	15-100	10-75	10-80	10-40
Pastoral (sedimentary, ash soils)	NA	30-45	20-30	25-35	25-40
Pastoral (pumice, peat)	60 - 75	55-70	NA	NA	NA
Urban[4]	<40	<30	<20	<25	<25
Forestry	<25				

- Soil orders with similar gravimetric values have been grouped and rounded to nearest 5 mg/kg
- Higher OP, trigger for evaluation of potential for WQ impacts, particularly for low P-retention soils

Macroporosity

- Based on a limited dataset of samples from untreaded/under fenceline pastoral land use (separate limited dataset for undisturbed forestry sites)

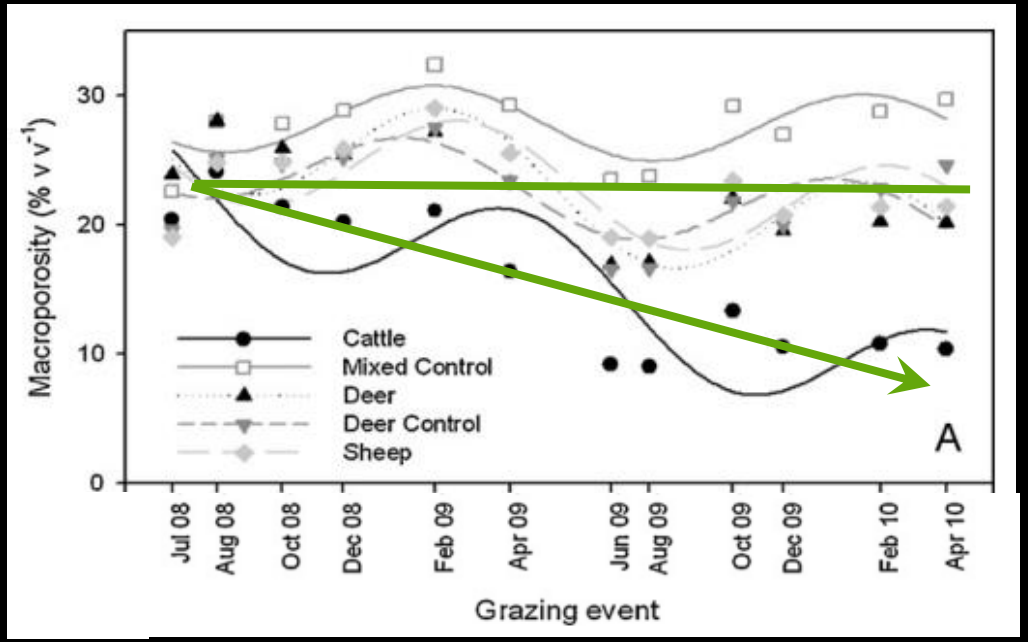
SoilOrder	n	median	10th%ile (%)	90th%ile (%)
Allophanic	5	14	**13**	**18**
Brown	3	18	**11**	**21**
Granular	6	12	**11**	**15**
Organic	10	17	**10**	**22**
Recent	4	16	**14**	**17**
Gley	4	15	**14**	**19**
Pallic	1	10	**10**	**10**
Podzol	2	30	**28**	**32**
Ultic	10	11	**9**	**15**

- Critical point
  - Some soils less resilient to compaction i.e. less likely to recover
  - Sensitive soils; Ultic, Pallic, Gley, Raw, Podzols, poorly-drained Recent
  - More resilient: Allophanic, Granular, Organic, Pumice, Brown, coarse well-textured Recent

Macroporosity

Land use	Reference range (%)
All land uses excluding forestry	10 – 22
Exotic forestry	12 – 35

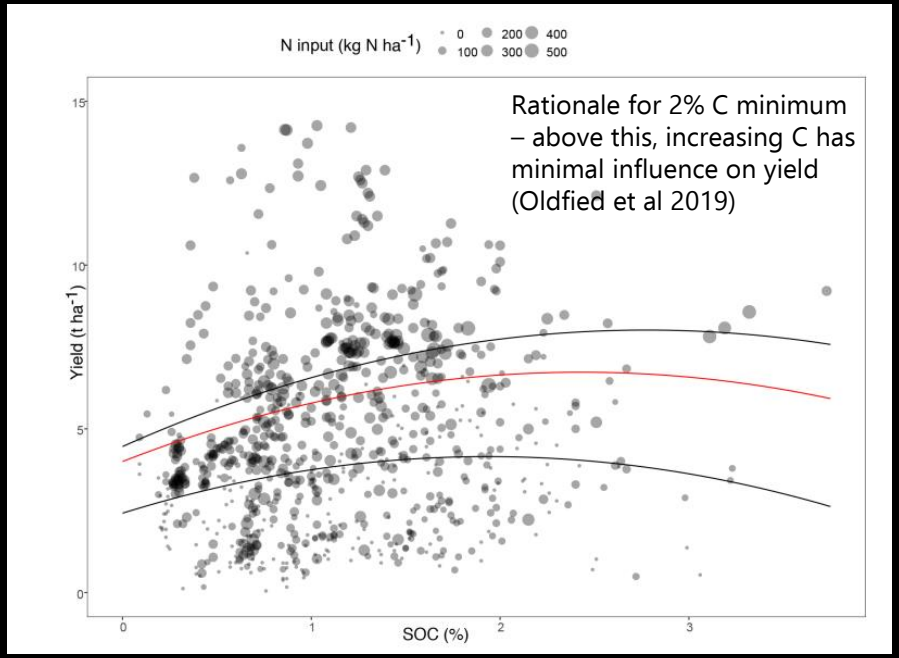
- Trend over time also important



Adapted from Curran-Cournane et al 2013

Total C

Land use group	Soil orders	Reference range
Cropping	Allophanic	4.0 – 8.0
	Others*	2 – 4.5
Orchard	Allophanic	5 – 10
	Others*	2.5 – 6
Vineyard	Others*	2 – 5
Dairy	Allophanic	6.5 – 13.5
	Others*	3.5 – 8.5
Drystock	Allophanic	5.5 – 13
	Others*	3.3 – 8
Exotic Forestry	Allophanic	6 – 18
	Others*	3.3 – 8
Indigenous Vegetation	Allophanic	5.5 – 18.5
	Others*	3.5 – 11
Urban Park/Reserve	Allophanic	4 – 10
	Others*	3 – 7
All	Raw	0.8 – 3



- Valuable to consider 'saturation deficit' based on mineral surface area

Approaches to assist interpretation

- Additional narrative to explain meaning/basis of reference range, significance of being outside this range and whether trend over time is more informative
- 'Traffic light' colouring for tables, e.g. Total C

Investigate/Action required
Review
Continue monitoring

Land use	<10%ile	10th%ile*	median	90th%ile	>90th %ile
Cropping	<2.0	2.0	2.7	4.5	>4.5
Dairy	<3.5	3.5	5.7	8.7	>8.7
Drystock	<3.3	3.3	4.8	8.3	>8.3
Exotic Forestry	<3.3	3.3	4.7	7.9	>7.9
Indigenous Vegetation	<3.6	3.6	5.9	11.3	>11.3
Orchard	<2.5	2.5	3.9	5.7	>5.7
Urban Park/Reserve	<2.8	2.8	5.1	6.8	>6.8
Vineyard	<2.3	2.3	3.5	4.8	>4.8

Concluding remarks

- We aren't much further advanced in our ability to develop thresholds/quantitative interpretations than early 2000s!
  - But we do have some better understanding of some processes – consequence often 'depends' on factors other than measured soil properties
  - **Targeted** research is required to better quantitatively link indicators to function and environmental responses

- Additional data is required for more robust macroporosity and bulk density reference ranges, carbon in Granular soils

- Modelling approaches required to better incorporate environmental considerations

- Key issues identified in the early 2000s (reduced macroporosity, excess Olsen P, low C in cropping soils) remain the key issues today – critical to consider how this information can be better used to effect positive changes in soil quality