Digging Deep:

Manaaki Whenua
Landcare Research

Improved Soil Water Retention Information in S-map

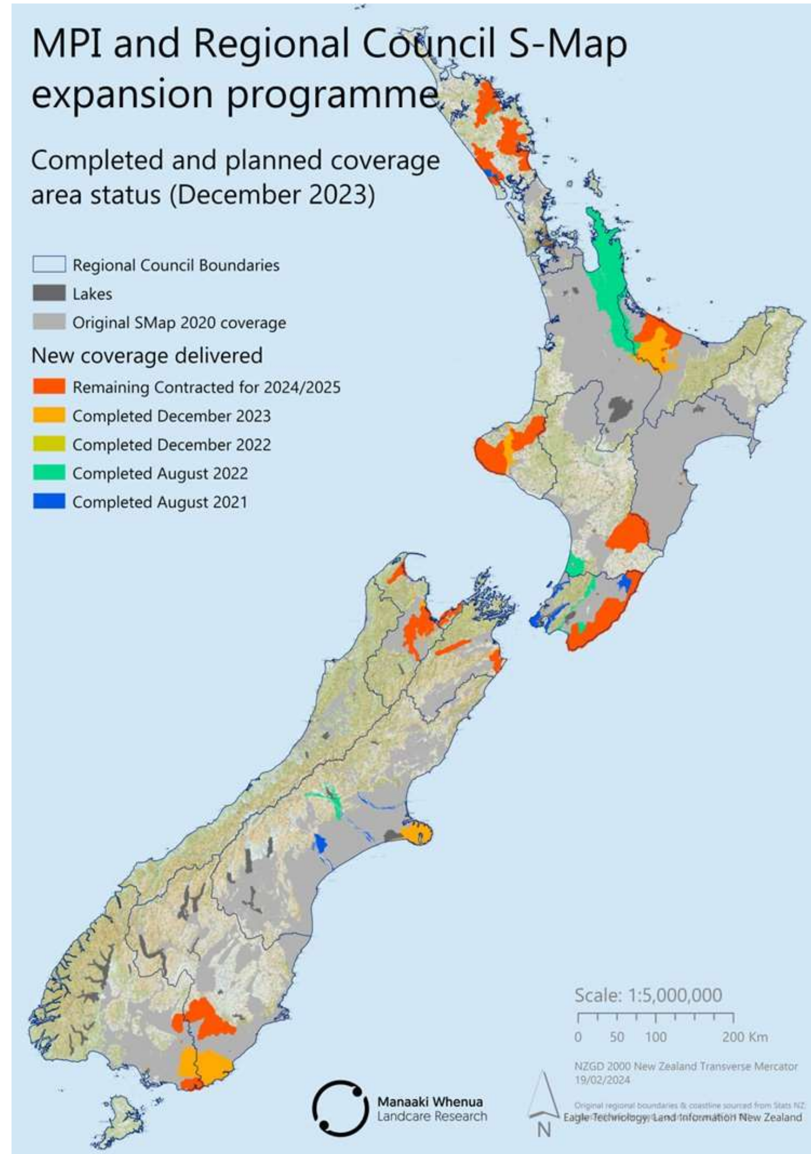
Linda Lilburne & Sam Carrick

MANAAKI WHENUA – LANDCARE RESEARCH

April 2024

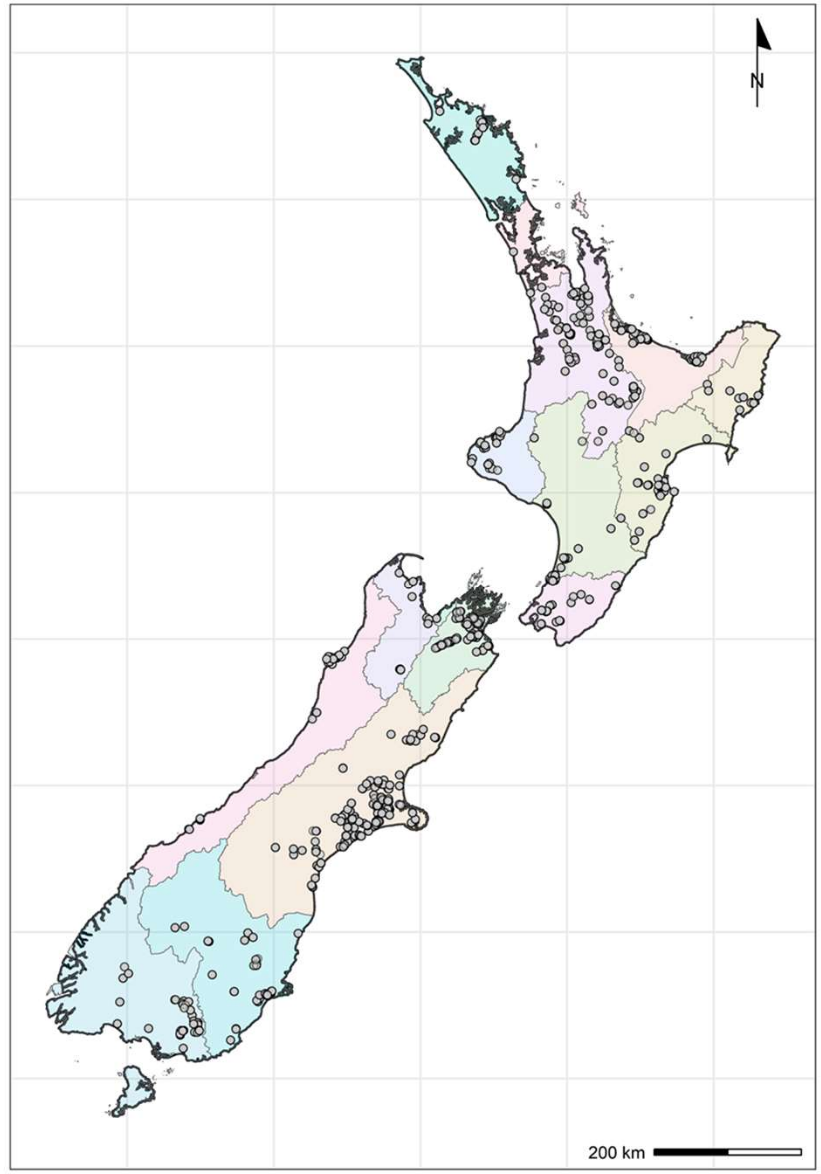
S-map coverage is expanding

- MPI and 12 Regional Councils have co-funded expansion of S-map coverage
- Since 2020, 1.45 million ha of new mapping has been added
- A further 1 million ha due for completion by August 2025
- Overall, ~7,000 different siblings (soil types) have now been identified

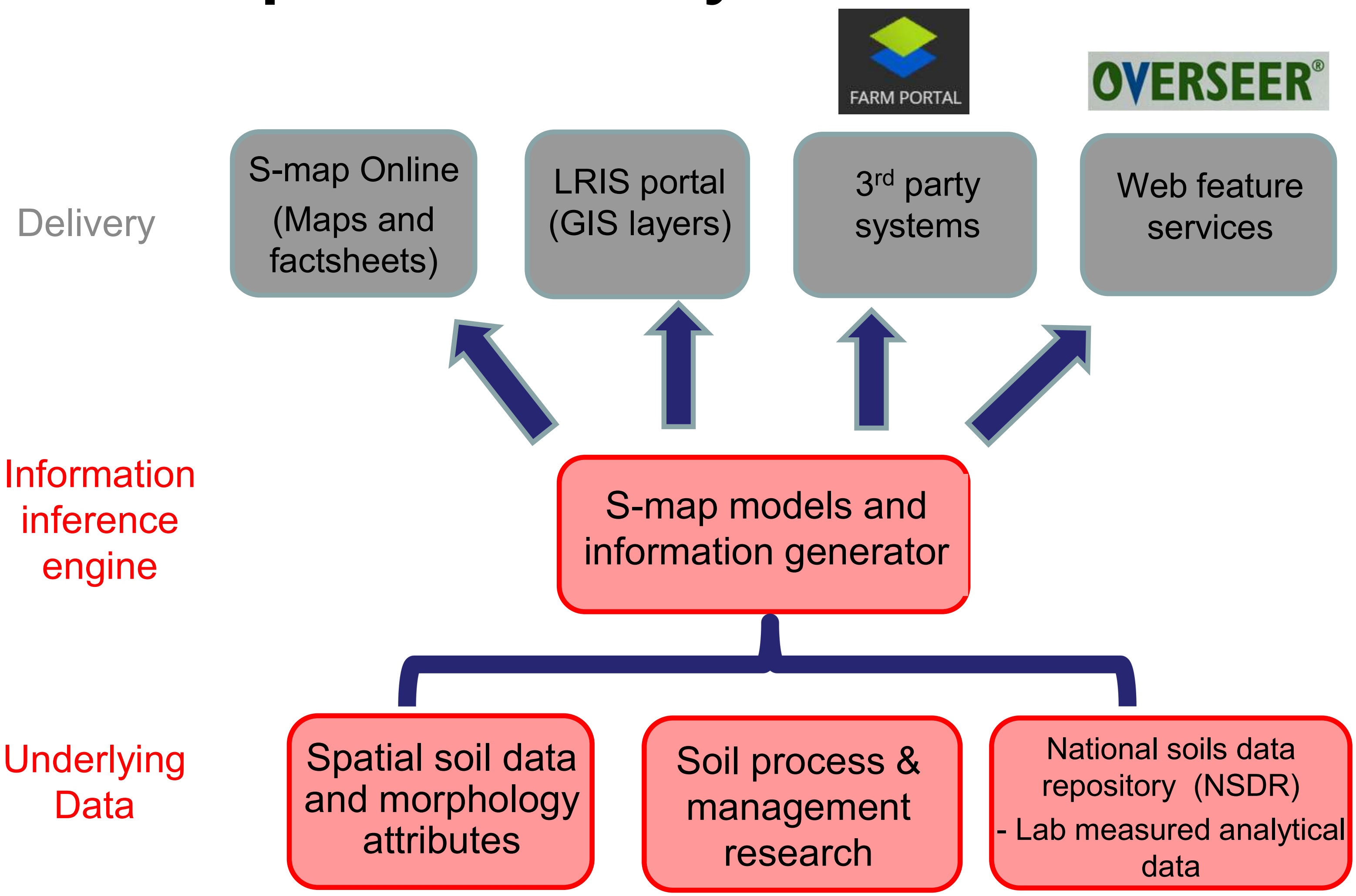


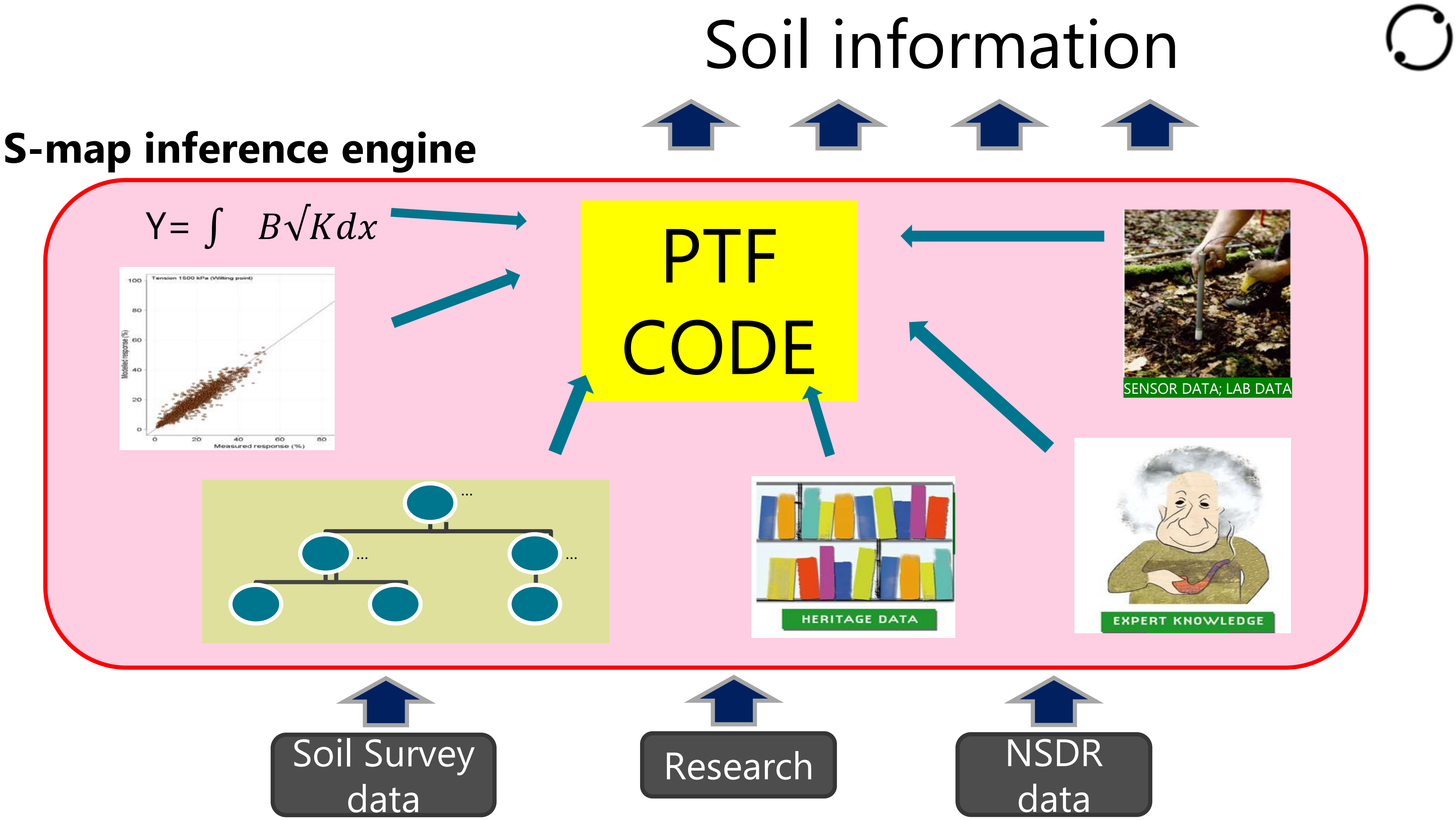
Reference sites have also increased

- Reference sites are used to estimate water retention for all S-map siblings
- Sites with lab measurements of soil water retention are costly (c.$10 000 / site)
- Between 2014 and 2020, addition of 371 sites doubled the dataset
- Since 2020 a further 112 sites (1315 samples) have been added



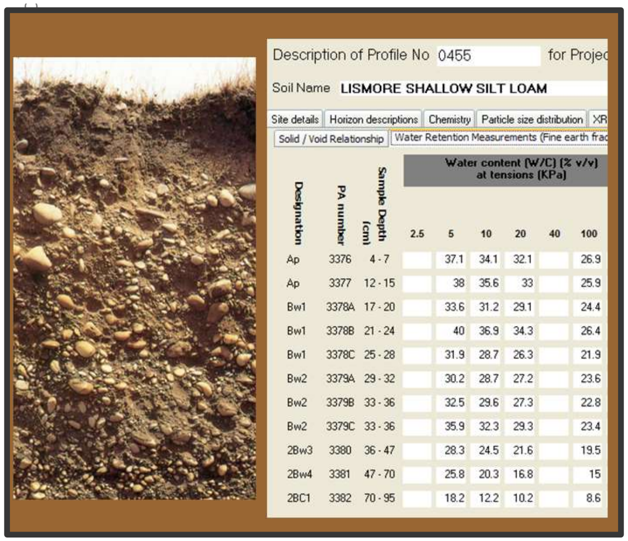
S-map information system





Soil information
S-map inference engine
Y= ∫ B√Kdx
PTF
CODE
SENSOR DATA; LAB DATA
HERITAGE DATA
EXPERT KNOWLEDGE
Soil Survey data
Research
NSDR data

Soil water retention pedotransfer function



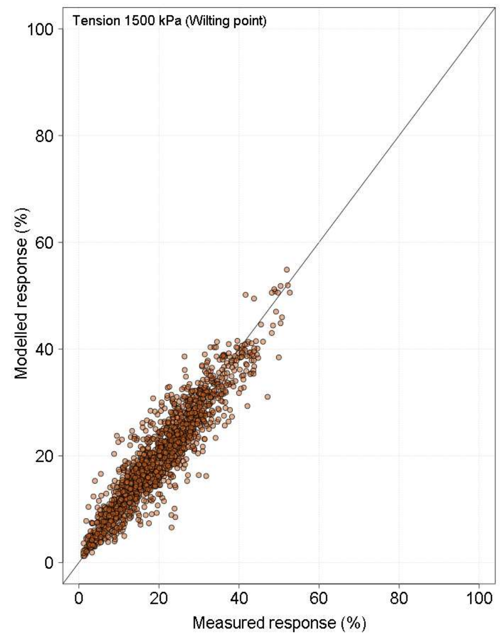
Description of Profile No 0455 for Projec

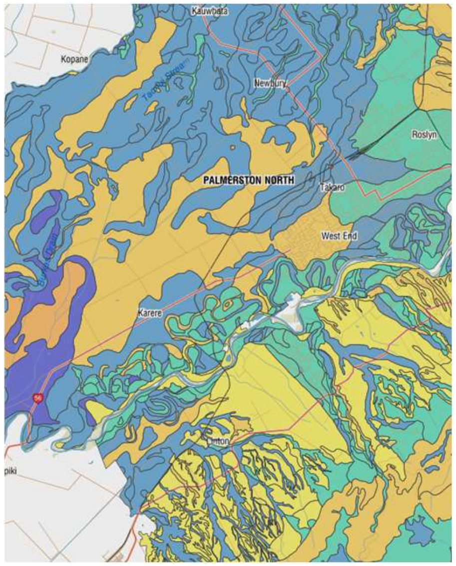
Soil Name LISMORE SHALLOW SILT LOAM

Site details | Horizon descriptions | Chemistry | Particle size distribution | XR

Solid / Void Relationship | Water Retention Measurements (Fine earth frac

Designation	PA number	Sample Depth (cm)	Water content (W/C) (% v/v) at tensions (KPa)					
			2.5	5	10	20	40	100
Ap	3376	4 - 7		37.1	34.1	32.1		26.9
Ap	3377	12 - 15		38	35.6	33		25.9
Bw1	3378A	17 - 20		33.6	31.2	29.1		24.4
Bw1	3378B	21 - 24		40	36.9	34.3		26.4
Bw1	3378C	25 - 28		31.9	28.7	26.3		21.9
Bw2	3379A	29 - 32		30.2	28.7	27.2		23.6
Bw2	3379B	33 - 36		32.5	29.6	27.3		22.8
Bw2	3379C	33 - 36		35.9	32.3	29.3		23.4
2Bw3	3380	36 - 47		28.3	24.5	21.6		19.5
2Bw4	3381	47 - 70		25.8	20.3	16.8		15
2BC1	3382	70 - 95		18.2	12.2	10.2		8.6





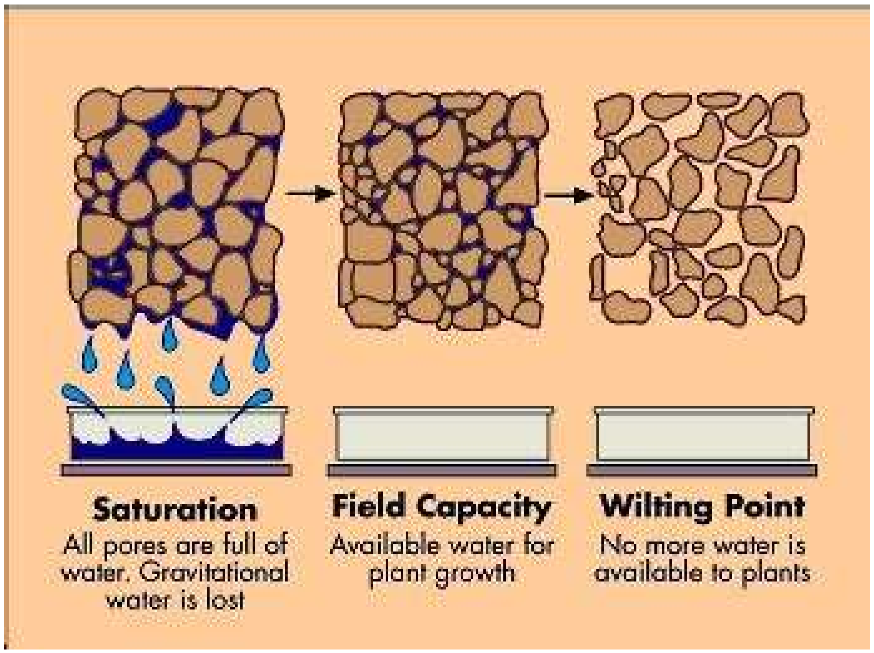
NSDR = lab measurements of soil attributes at a point location

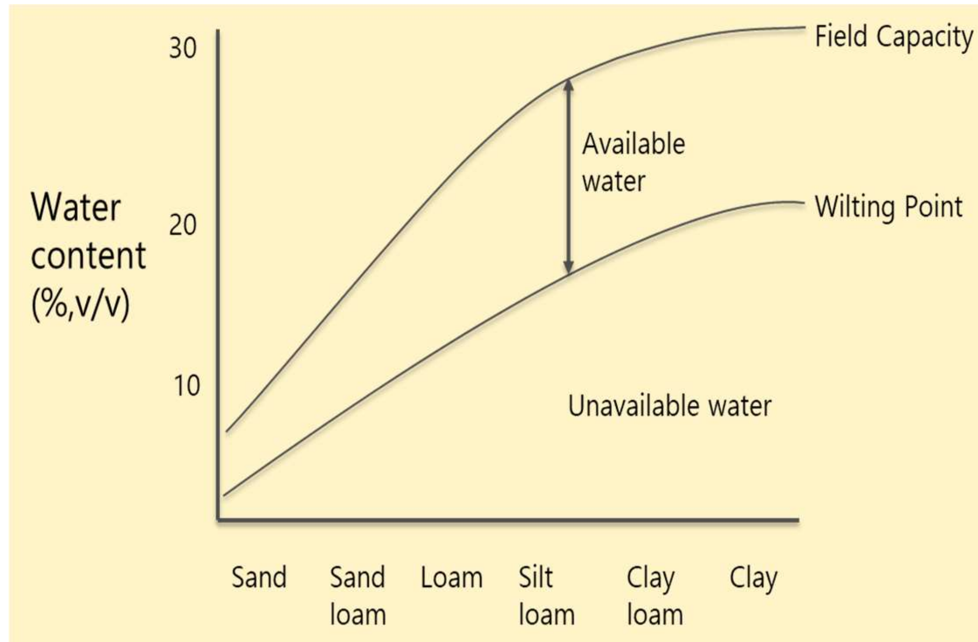
Statistical modelling of soil attributes

S-map = spatial variability (PAW)

Update and implications of the 2024 S-map PTF for predicting soil water retention

Soil Water Retention?





Additional data

- Laboratory data: mix of new and legacy data sources
- QA
- Significant increase in amount of data

	Total number sites		S-map area	Total samples	
Soil Order	**2020**	**2024**	**Mha**	**2020**	**2024**
Allophanic	42	64	**1.1**	264	554
Allophanic Brown	21	25	0.2	134	164
Granular	4	7	0.1	33	51
Immature Gley	24	19	0.1	196	148
Immature Pallic	101	110	0.5	655	958
Mature Gley	103	125	0.7	709	1005
Mature Pallic	72	81	**1.1**	595	743
Melanic	13	14	0.2	99	104
Non-allophanic Brown	139	159	**2.6**	726	841
Organic	5	9	0.1	41	57
Oxidic	8	8	0	58	51
Podzol	29	30	0.4	206	210
Pumice	18	28	**1.2**	108	157
Recent	85	93	**1.3**	634	691
Semi-arid	11	10	0.1	97	98
Ultic	9	14	0.1	86	124
Total	**684**	**796**	**10.3**	**4641**	**5956**

Article

An improved pedotransfer function for soil hydrological properties in New Zealand

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Featured Application:

Landowners, regional and national governments, and researchers can use predictions of the soil hydrological properties created in this work, such as wilting point, field capacity, macroporosity, and total available water, to characterize soils for soil management decisions, e.g. in terms of irrigation requirements, or for policy, e.g. nutrient budgets and regulations.

Abstract: This paper describes a new pedotransfer function (PTF) for the soil water content of New Zealand soils at seven specific tensions (0, –5, –10, –20, –40, –100, –1500 kPa) using explanatory variables derived from the S-map soil mapping system. The model produces unbiased and physically plausible estimates of the response at each tension, as well as unbiased and physically plausible estimates of the response differences that define derived properties (e.g. macroporosity and total available water). The PTF is a development of an earlier model [1], using approximately double the number of sites compared with the earlier study, a change in fitting methodology to a semi-parametric GAM Beta response, and the inclusion of sample depth. The results show that the new model has resulted in significant improvements for the soil water content estimates and derived quantities using standard goodness-of-fit measures, based on validation data. A comparison with an international PTF using explanatory variables compatible with variables available from S-map (EUPTF2) suggests that the model is better for prediction of soil water content using the limited information available from the S-map system.

Keywords: soil water content; pedotransfer function; soil hydrological properties; generalized additive models.

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1. Introduction

Soil hydraulic modeling aims to estimate key parameters relating to the retention of water in the soil matrix. These parameters are used in a wide range of modeling applica-

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Pedotransfer functions for the soil water characteristics of New Zealand soils using S-map information

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ABSTRACT

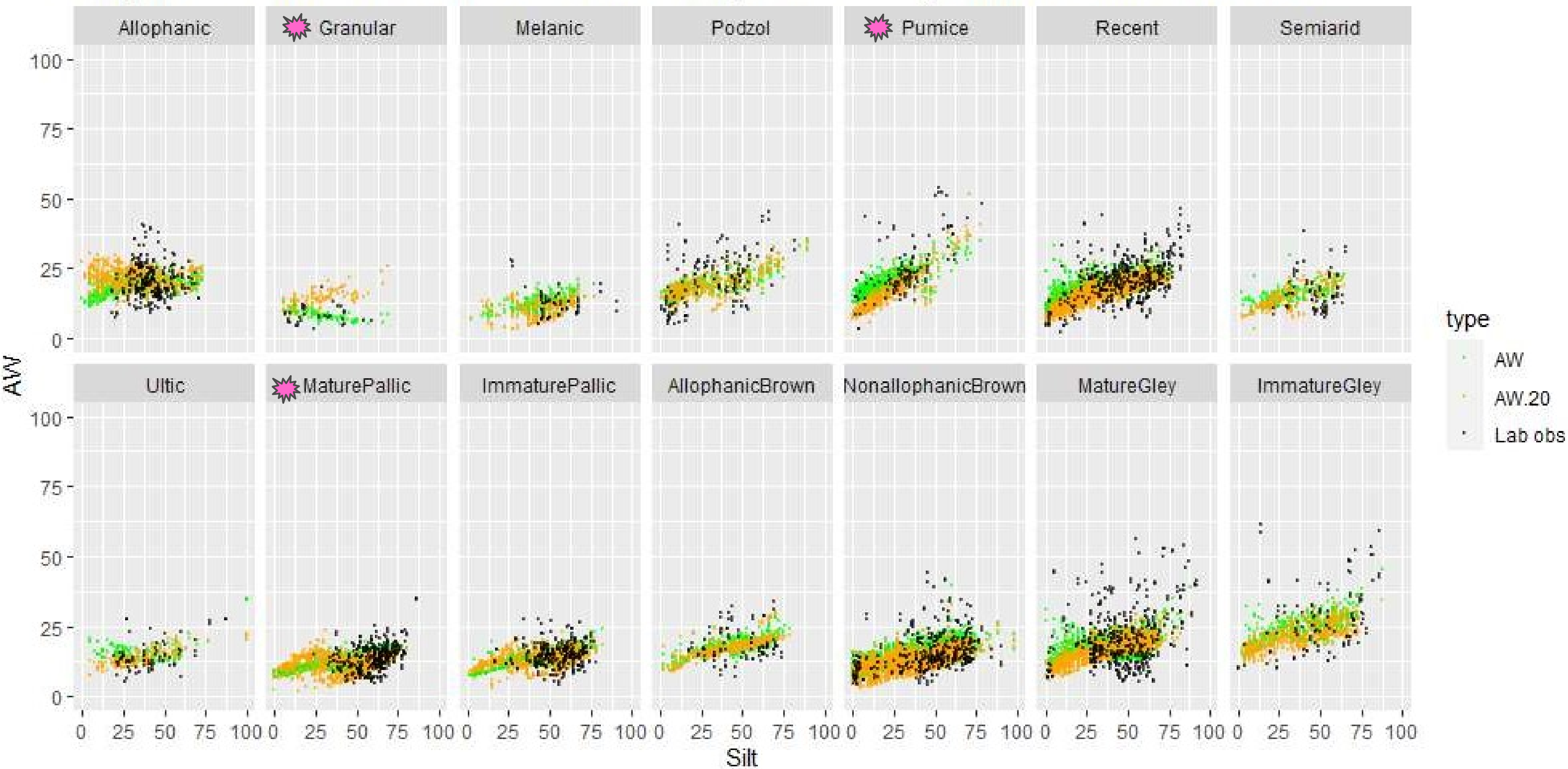
Empirical pedotransfer functions (PTFs) have been developed for estimates and the uncertainty of soil water content at different tensions, using explanatory variables from a soil information system for New Zealand (S-map). The explanatory variables include the soil order classification, texture, and parsed information from the S-map functional horizon description. Three models have been considered. The first uses a linear model based on the logit transformation to convert the bounded soil water response range to unbounded form. The second uses beta regression, which models the location and scale of the response separately. Finally, we consider a common response model that includes the tension as an explanatory variable to fit the soil water response at all tensions.

A feature of the PTFs is the consistent development of the uncertainty of estimates. All regressions are constrained within the range bounded by 0 and 100%, while the logit transformation and beta regression models are constrained so that response differences are bounded; this ensures that the response is monotonic with respect to tension. For the logit and beta regression methods, the constraint of range (0–100%), monotonicity, and order of uncertainty calculation are simultaneously maintained for all tensions, ensuring that derived estimates such as total available water (TAW), and macroporosity, and their uncertainty, are physically consistent.

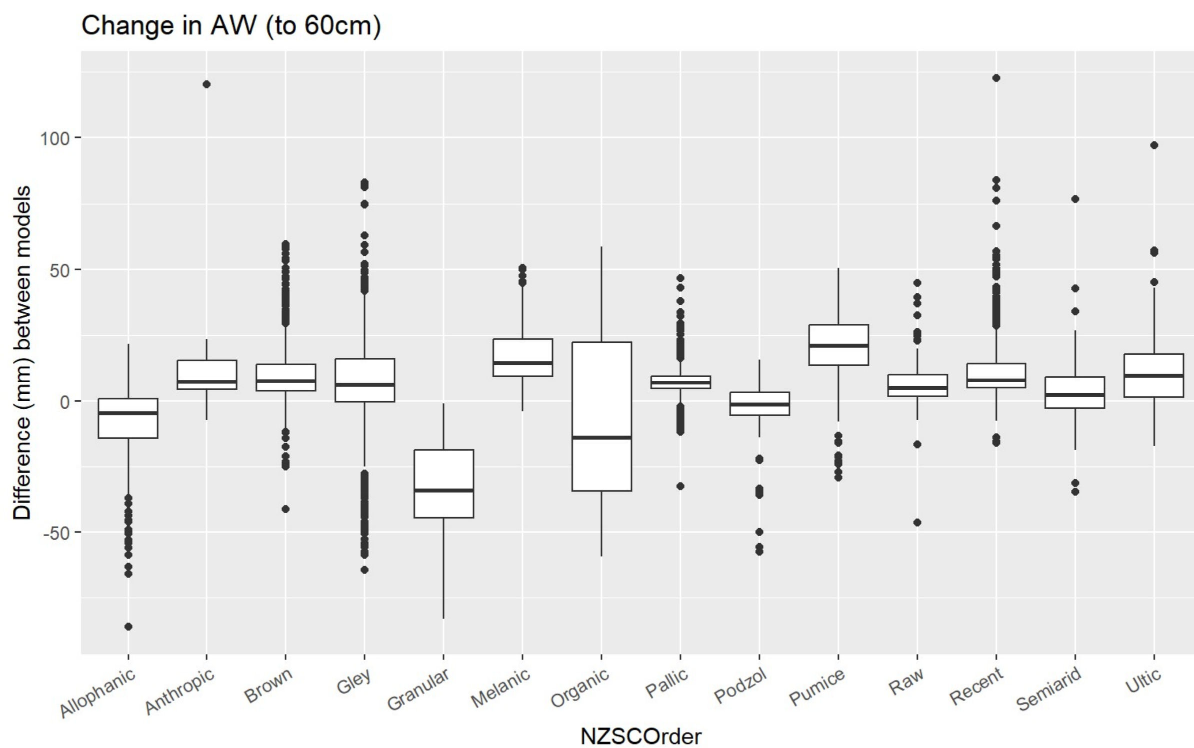
The available data was split between a fitting and an independent validation dataset used for verification of the uncertainty model. Using the independent validation dataset, none of the models showed any evidence of over-fitting. The logit-transformation model was selected because it provided the lowest reliable estimate of mean absolute error and root mean square error in soil water response, TAW, and macroporosity, with uncertainty estimates based on posterior simulation. In the case of certain soil orders, a bias in the estimated TAW is evident at high values, although its origin is not clear. The selected model is used as the soil hydraulic response pedotransfer function used in the S-map inference engine to provide estimates of water content and available water for a wide range of New Zealand soils.

2020 model	2024 model
Beta Regression (McNeill et al. 2018) Default values for Organic horizons	GAM Regression (McNeill et al. submitted) Specific model for Organic horizons
684 sites	796 sites
Samples used to train the model: 3,713	4,169 samples
Samples used to validate the model: 928	1,787 samples
Significant increase in samples – variable coverage of key soil orders	Most soil orders increased by ~40-50%, but some still have low site and sample numbers
Improvement in goodness-of-fit metrics	Further improvement in goodness-of-fit metrics
Limited error model	Full error model
4 sibling horizons in S-map cannot be predicted Additional assumptions were needed to cope with insufficient data	More robust: all sibling horizons in S-map can be predicted. Only two additional assumptions needed now (Raw soils are treated as Recent or Gley, high clay Pumices treated as Brown)

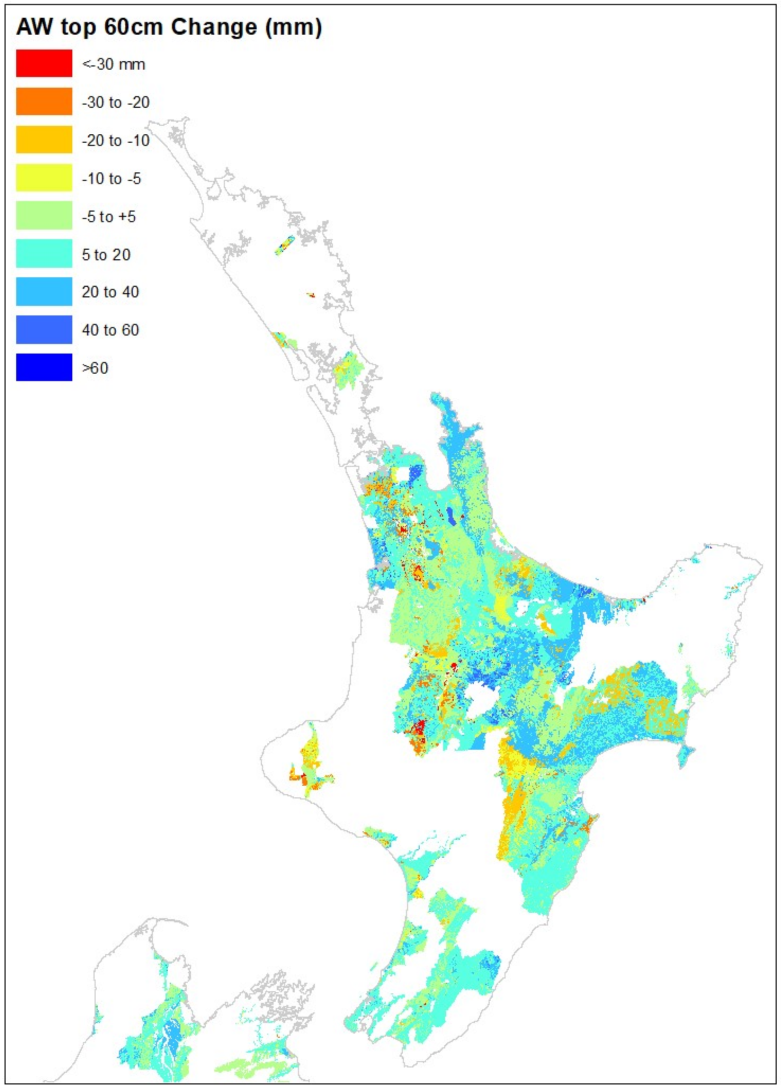
Smap horizon estimates and measurements

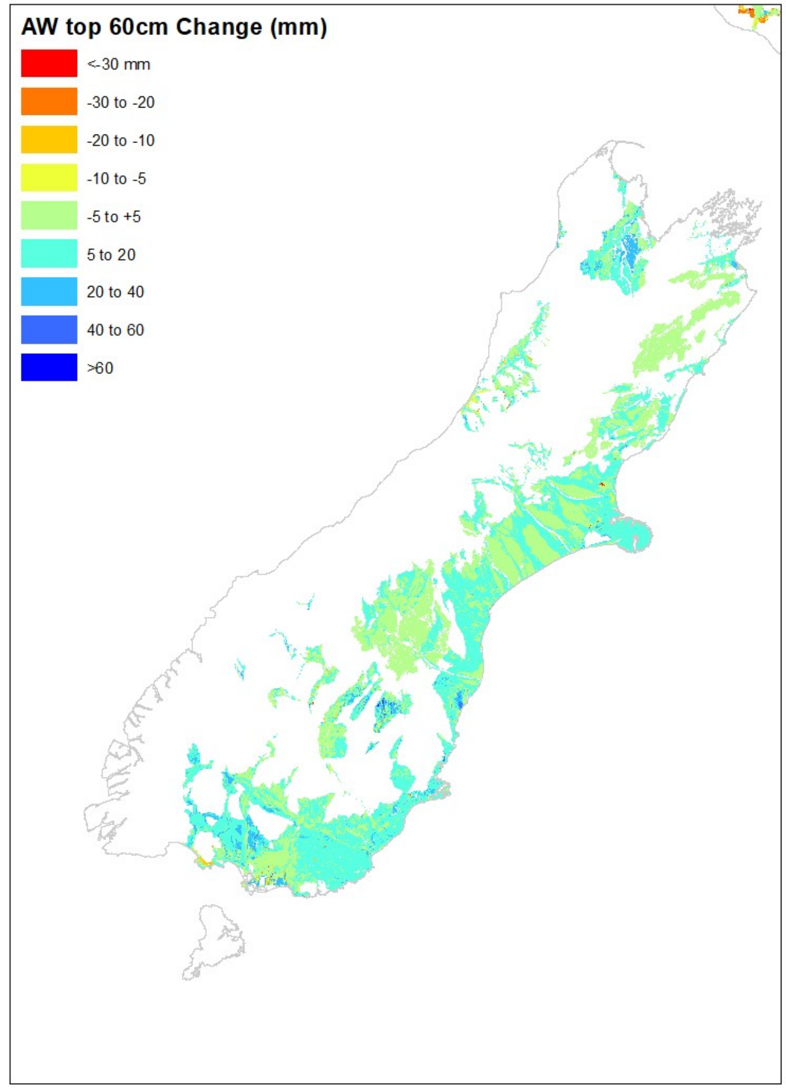


NZSC Order	AW60 2020 median change (mm)	Smap area (Mha)
Allophanic	-4.7	**1.1**
Anthropic	7.45	<0.1
Brown	7.7	**2.7**
Gley	6.1	0.8
Granular	-33.9	0.1
Melanic	14.5	0.1
Organic	-14.0	0.1
Pallic	7	**1.6**
Podzol	-1.35	0.4
Pumice	21.2	**1.2**
Raw	4.95	0.4
Recent	8	**1.3**
Semiarid	2.15	0.1
Ultic	9.7	0.2
Overall	**6.9**	**10.3**



S-map water retention model 2024



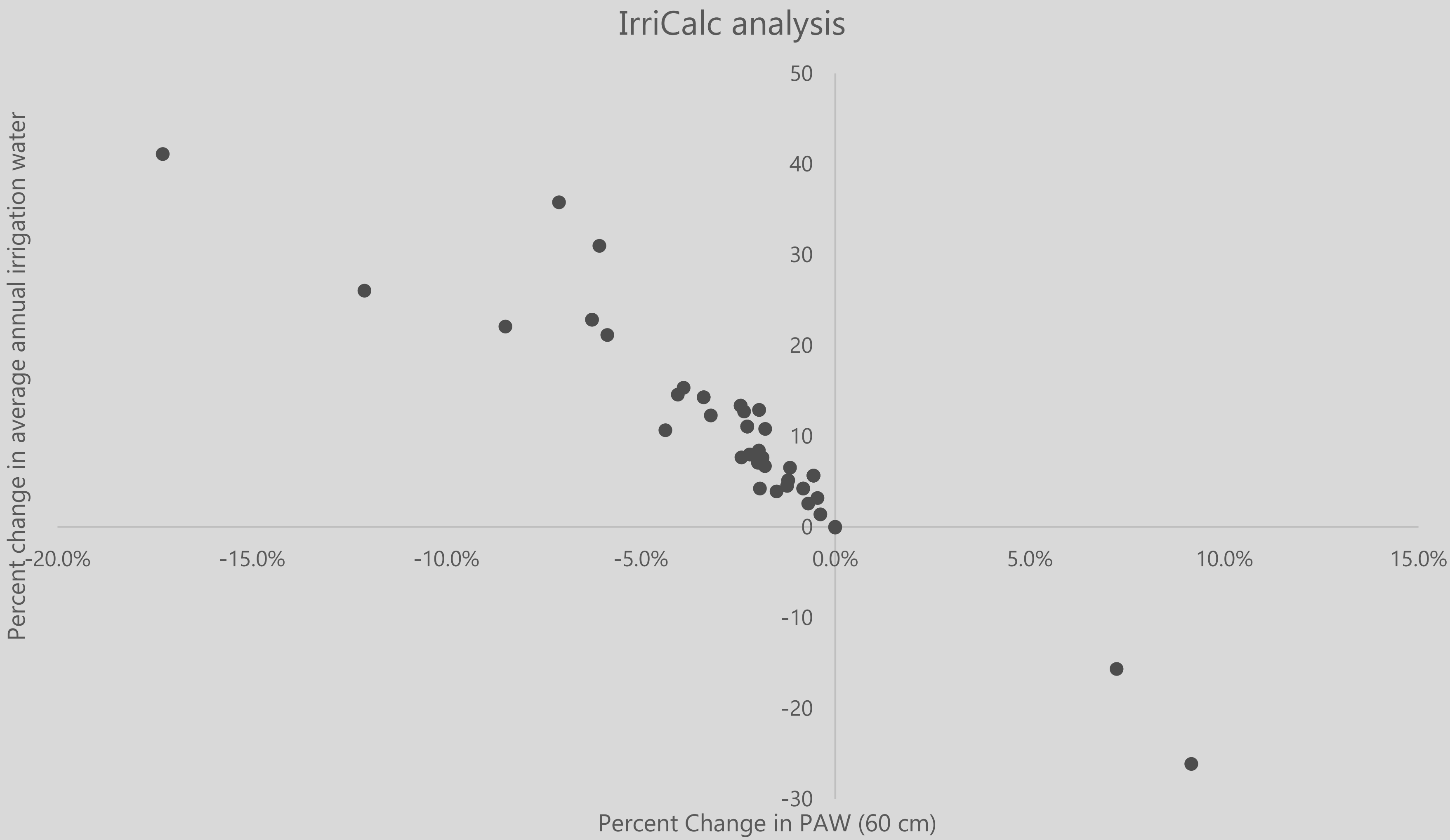


Overseer impact analysis

Nutrient budgets will **not** be auto-updated

Percentage change in N loss/ha	Farm count	%
> 50% increase	4	0.1%
> 40% increase	3	0.0%
> 30% increase	6	0.1%
> 20% increase	21	0.3%
> 10% increase	58	0.9%
0 to 10% increase	276	4.3%
no change	2358	36.3%
0 to 10% decrease	2295	35.4%
> 10% decrease	1177	18.1%
> 20% decrease	246	3.8%
> 30% decrease	37	0.6%
> 40% decrease	6	0.1%
> 50% decrease	5	0.1%

Irricalc impact analysis



Key messages

- S-map is science driven (which means change from time to time)
- Better information for farm management & environmental outcomes
- Significant investment in reference site measurements over the last decade

Updated national model

- Improvement in the soil water retention model robustness
- National scale model -> all soil moisture data values will change

Acknowledgements: MBIE, MPI, Regional Councils, farmers