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Evaluation of S-map water retention predictions, by comparison with Wairau Valley soil sample data

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Evaluation of S-map water retention predictions, by comparison with Wairau Valley soil samples

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Contents

Summary

Pedotransfer functions (PTFs) developed in the S-map database, from the National Soils Database, predict water content based on New Zealand Soil Classification soil order, texture, and other information from S-map functional horizon descriptions. In this study, these predictions are compared with measured soil data from an independent soil survey from the upper Wairau Valley in Marlborough, in which soil samples were analysed in the laboratory for their texture and moisture retention properties. The soil survey pit descriptions were used to classify each sampled horizon according to New Zealand Soil Classification soil order and S-map functional horizons, and thus make predictions of the soil water content according to the S-map water retention PTFs.

Laboratory-measured water content values were then compared with S-map predictions for these soil horizons. S-map predictions are accurate for wilting point, but less so for field capacity. Predictions for available water are on average low for topsoil and slightly high for subsoil, and have low correlation with measured values and high uncertainty on the very lowest available water values. Available water predictions are better for subsoil than for topsoil, and better for Recent Soils than for Brown Soils. They tend to be too high for high-sand and too low for high-clay content soils.

The development of S-map PTFs is limited by the quality and quantity of the measured soil data for New Zealand that are stored in the National Soils Database. It may be that the Wairau Valley soils are not well represented in the National Soils Database training data[1] used to develop the water retention PTFs. In terms of the sampled data from the Wairau Valley, the topsoil sampling depth of 0 to 7.5cm may not be representative of the whole of the top functional horizon. The S-map PTF was developed using historical samples that were taken at the midpoint of the soil horizon.

This analysis is based on a very limited data set over a very limited geographical area, so more general conclusions about the accuracy of the PTFs cannot be drawn. It does highlight the importance of extending the existing training data set for the S-map PTFs. This could be facilitated by capturing and storing laboratory data from legacy soil surveys, like that for the upper Wairau Valley, in the National Soils Database for use in future PTF development.

[1] Dataset extracted from the NSD that is cleaned and reformatted for statistical analysis

1 Introduction

Pedotransfer functions (PTFs) have been developed in the S-map database for predicting soil water content at different tensions, using explanatory variables that include the New Zealand Soil Classification (NZSC) soil order, texture, and other information from S-map functional horizon descriptions. The soil data used to derive the PTFs are derived from New Zealand's National Soils Database.

2 Background

2.1 Soil water retention properties

The volumetric water content of a soil is the volume of water per volume of soil. It ranges from 0% (completely dry soil) to when soils are saturated at water contents that can vary between 40 – 80%, depending on soil type. The water retention curve is the relationship between water content and tension applied to the soil. Some important values on the curve are:

- total porosity – the maximum amount of water able to be held in the soil when all pores are full (saturated) and before drainage takes place (water content at 0 kPa tension)
- field capacity – the total amount of water that a soil contains after water has drained away by gravity over a period of 2 days after it has been saturated by rainfall (taken in New Zealand as water content at -10 kPa tension)
- wilting point – the minimal point of soil moisture that plants require not to wilt (water content at -1,500 kPa tension).

Other values are derived from the water retention curve, including available water (AW) – the maximum amount of plant-available water a soil can provide, which is calculated as the difference between water content at field capacity and wilting point.

2.2 S-map water retention curve pedotransfer functions

Soil hydraulic properties are used in a wide range of applications, but the data collection and laboratory analysis required for their measurement is costly and time-consuming. A soil hydraulic PTF aims to provide an estimate of water retention curve values for a soil, based on easily measured soil properties. A statistical model is built from a data set of field and laboratory data, then the soil property relationships in that model can be applied to other soils with similar field data. During the modelling process, a range of possible explanatory soil properties are investigated and the most statistically important are chosen. Lack of soil sample data may restrict the scope and accuracy of a PTF.

The PTFs used for S-map water retention since 2014, developed at Manaaki Whenua – Landcare Research (McNeill et al. 2012, 2018), use soil data from the National Soils Database[2]. Linear or generalised linear models with interactions were developed for each of seven key points on the water retention curve (0, 5, 10, 20, 40, 100, and 1,500 kPa tension). The PTFs also produce an estimate of the uncertainty of a predicted value. The explanatory soil properties for this PTF are:

- NZSC soil order and group (Hewitt 2010)
- soil texture – percentage sand, silt and clay
- rock type
- functional horizon code (Webb & Lilburne 2011), based on topsoil/subsoil, stone content, texture of fines, structure size and consistence.

3 Objectives

The objective of this analysis is to compare the S-map predicted water content values with measured values, using laboratory results from samples taken at a number of sites in the Wairau Valley in Marlborough during May 2015.

4 Soil survey methods

Soil profile descriptions and photographs for 36 profiles from the upper Wairau Valley in Marlborough have been entered into the S-map database of Manaaki Whenua – Landcare Research. This provides the fundamental soil inputs required by PTFs to calculate water content, for comparison with measured values.

Data sources for this work included both a comprehensive MS Excel file prepared by the soil surveyor Ian Campbell, and derived soil descriptions in Appendix B, Technical Report 16-005, for Marlborough District Council (August 2016). In the few instances where the two data sources disagreed, preference was given to the MS Excel spreadsheet as the original source.

Described soil depths varied between 55 and 90 cm. As S-map describes soil to a depth of 100 cm, an artificial soil horizon was entered, bringing all soil profiles to a uniform depth of 100 cm. The properties for this additional artificial horizon were copied from the lowermost described horizon. Based on texture, ped size and soil consistence, the soil horizons for each profile were grouped into functional horizons (i.e. horizons that 'behave' similarly in terms of soil hydrological processes and are used in S-map to predict soil characteristics such as profile available water and hydraulic conductivity). The artificial horizons were assigned the same functional horizon as the lowermost horizons described.

[2] The National Soils database is a 'point' database representing profile data collected for over 1,500 soil pits scattered throughout New Zealand (not including the Wairau Valley data). Data are classified under the NZSC, comprising the soil description by horizon, and physical and chemical analyses.

Soil samples were collected from the two top-most functional horizons only (topsoil and subsoil). Particle size and moisture release analyses were performed at Manaaki Whenua – Landcare Research's Hamilton Soil Physics Laboratory. Laboratory results for soil texture were used to confirm the texture classes assigned during the survey. The texture class needed correction only in a few instances[3]. Texture results for topsoils of WV25 and WV28 showed clay contents slightly above 35%, but it was decided to retain the field assessment of silt loam, as the lab sample was only taken from the top 7.5 cm of the A horizon and is not representative of the entire functional horizons of these profiles (17 and 19 cm, respectively).

All available soil information was used to classify the 36 profiles according to the NZSC soil orders (Hewitt 2010). This yielded 24 Brown, seven Recent, three Pallic and two Gley Soils.

As a last step, all available information was entered into the S-map database. For each profile, this generated a soil family and sibling (4th and 5th category of the NZSC; Webb & Lilburne 2011), with key soil physical properties assigned to each sibling. The S-map database ran the PTFs for soil water content as each of the 36 profiles was entered.

5 Results

The following analyses are based on 67 samples: 36 topsoil and 31 subsoil.[4,5,6] A single uncertainty value was calculated per sample (standardised uncertainty in prediction of wilting point, with values ranging from 0.09 to 0.4) and indicated on graphs by a ramp from black at low uncertainty to red at high uncertainty.

5.1 Available water (AW) %

Table 1 Comparison of S-map estimates of AW with measured data

Average	*Topsoil*	*Subsoil*
S-map	20.6	16.3
Measured	25.1	14.9
Difference = S-map – Measured	–4.5	1.4

[3] Profile WV23: A and AB horizon re-classified from clay loam to loamy clay; profile WV33: A horizon re-classified from loamy sand to sandy loam; profile WV35: all horizons re-classified from silt or clay loam to silty clay.

[4] At two sites there are vineyards, and topsoil samples were taken both near a vine and away from vines. The under-vine samples have been excluded from the analysis because S-map's water retention prediction is based on pastoral soils. The two excluded samples had lower measured AW values than the non-vine samples at the same site: 19.8 vs 25.9 and 20.4 vs 25.2 %AW.

[5] At two sites the depths of the subsoil samples meant they covered both the two upper-most functional horizons. Since their texture results were more similar to the top horizon than to the second-to-top, they have been treated as topsoil for the analysis.

[6] Three sites had very stony subsoil (>15% stones) and were excluded from the analysis.

Correlation S-map : Measured	0.3	0.1

S-map predictions of topsoil AW are on average 4.5 percentage points lower than measured values. S-map predictions of subsoil AW are slightly higher than measured values. Values of AW for all soils in S-map are mostly in the range 15 to 30% for the first functional horizon and 10 to 25% for the second horizon, so AW values for Wairau soils (19 to 21% topsoil and 14 to 17% subsoil) are not uncommon in comparison to soils mapped elsewhere.

5.1.1 Topsoil

- The differences are mostly below zero (negative) because S-map predictions of topsoil AW are mostly lower than measured values.
- The differences between S-map predictions and measured values do not show any systematic pattern as the estimated AW value increases.
- S-map predictions do not reflect the measured variability. They had relatively constant values (around 19–21% AW) for many Wairau topsoils.
- There is a positive but low correlation of 0.28 between S-map predictions and measured values of topsoil AW.
- The lowest predicted AW values are the most different to measured values and have higher uncertainty (shown in red on the graphs) than other predictions. There are no high over predictions.

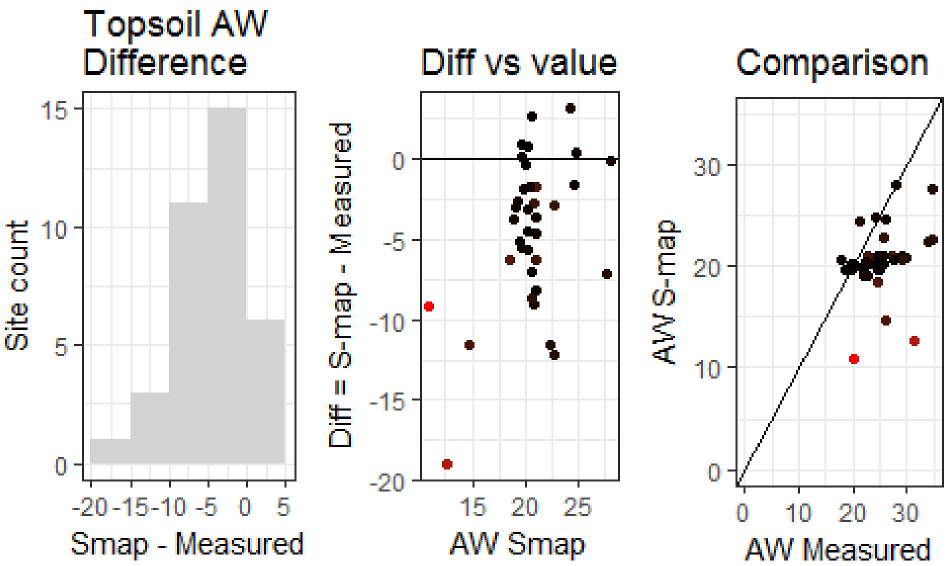

Figure 1 Plots showing a histogram of the differences in topsoil AW, the difference vs the AW estimate and the measured vs the estimated AW(%) value.

5.1.2 Subsoil

- S-map predictions of subsoil AW are closer to measured values than for topsoil.
- S-map predictions tend to overestimate at higher AW.
- S-map predictions vary less between different soils, giving relatively constant values (around 14–17% AW) for many Wairau subsoils.

- There is a positive but very low correlation of 0.12 between S-map predictions and measured values of subsoil AW.
- The one very low predicted AW value has higher uncertainty (shown in red on the graphs) than other predictions, but the values that are predicted too high do not have high uncertainty.

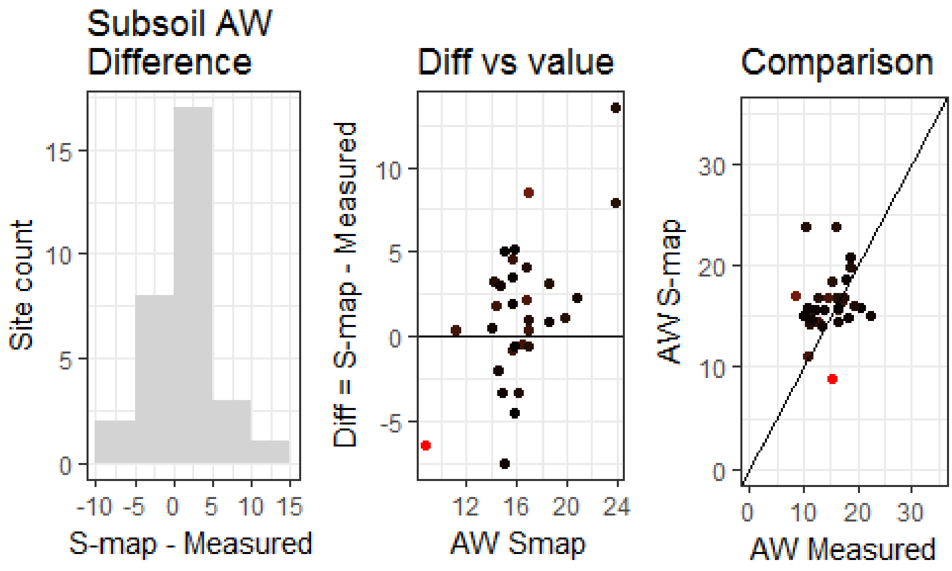

Figure 2 Plots showing a histogram of the differences in subsoil AW, the difference vs the AW estimate and the measured vs the estimated AW(%) value.

5.1.3 Comparison by soil order

S-map predicts AW more accurately for Recent Soils than for Brown Soils in the Wairau Valley. Other soils have too few samples to evaluate.

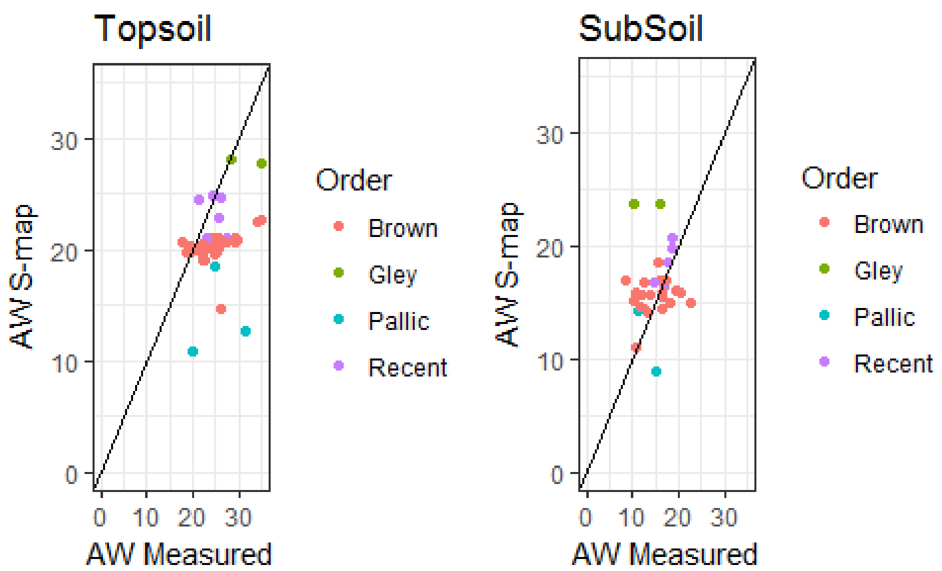

Figure 3 Comparison of measured with estimated values of AW(%) by soil order.

5.1.4 Comparison with texture

Nearly all the Wairau Valley soils are silt loams and have a texture that is typical of loess-influenced soils. There may be a pattern for differences in AW (between S-map predictions and measured values) when related to more extreme soil textures, although there are only a few data points:

- At high clay content (>35%) S-map tends to under-predict AW.
- At high sand content (>35%) S-map tends to over-predict AW.
- The largest uncertainty is at very low sand / high clay content.

In soils with less extreme sand and clay content, S-map predictions of AW are a mixture of over and under the measured values.

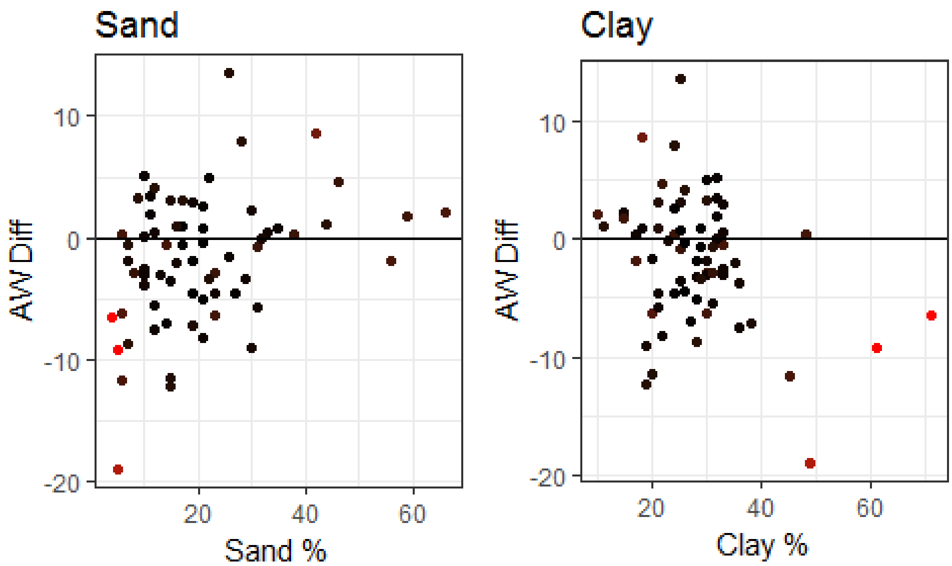

Figure 4 Plot of differences in AW by sand and clay content.

5.2 Other water content values

- S-map estimates of wilting point are the most accurate of the water retention curve values being compared, having small average differences to measured values and high correlation (topsoil 0.7, subsoil 0.9).
- Estimates of field capacity are less accurate, especially for topsoil, where S-map predictions are generally lower than measured and less correlated.
- AW is the difference between wilting point and field capacity, so the accuracy of predictions is affected by both these values. For topsoil, AW predicted values are lower than measured (as already noted) due to prediction of field capacity being lower than measured. For subsoil, AW predicted values are slightly higher than measured because prediction of wilting point is slightly lower and prediction of field capacity slightly higher than measured.

- Total porosity predictions are the least accurate of the water content values, and total porosity is over-predicted on average for subsoil.

Tables 2–4 and figures 5 and 6 show the differences between estimated and measured total porosity, field capacity and wilting point.

Table 2 Total porosity (%)

Average	*Topsoil*	*Subsoil*
S-map	56.8	49.1
Measured	56.2	45.9
Difference = S-map – Measured	0.6	3.2
Correlation S-map : Measured	–0.1	0.3

Table 3 Field capacity (%)

Average	*Topsoil*	*Subsoil*
S-map	39.5	35.8
Measured	44.1	35.2
Difference = S-map – Measured	–4.6	0.6
Correlation S-map : Measured	0.4	0.8

Table 4 Wilting point (WP) %

Average	*Topsoil*	*Subsoil*
S-map	18.9	19.5
Measured	18.9	20.3
Difference = S-map – Measured	0.0	-0.8
Correlation S-map : Measured	0.7	0.9

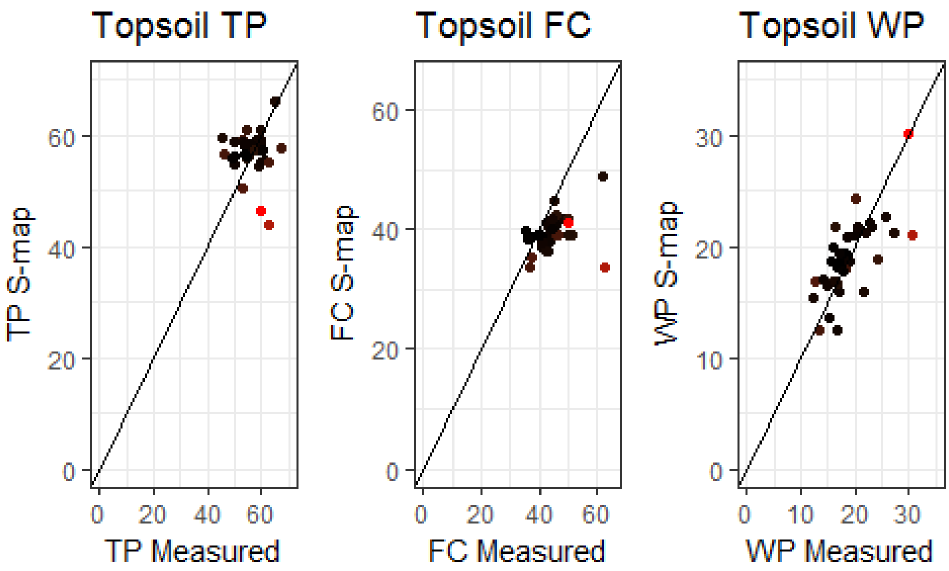

Figure 5 Comparison of measured vs estimated values of topsoil total porosity (TP), field capacity (FC) and wilting point (WP).

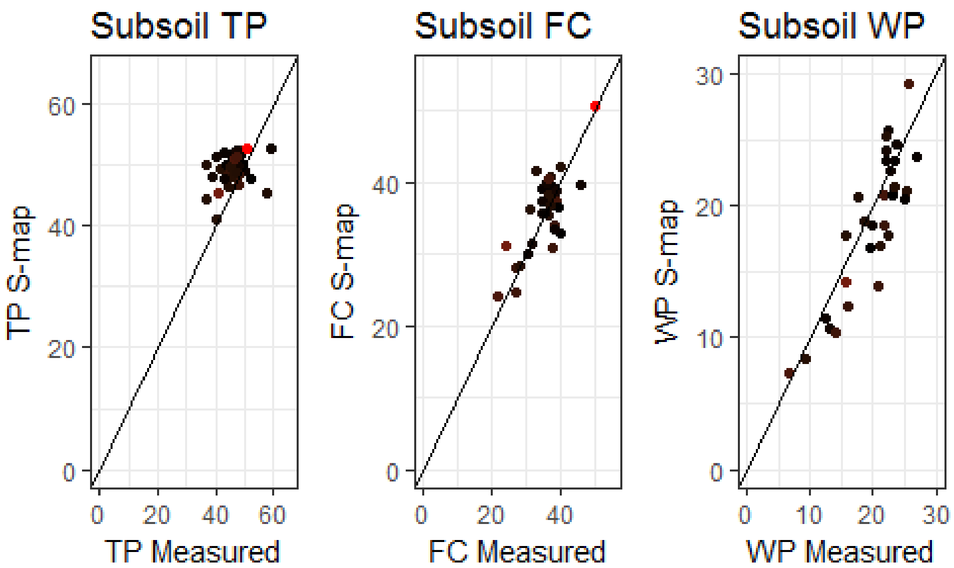

Figure 6 Comparison of measured vs estimated values of subsoil total porosity (TP), field capacity (FC) and wilting point (WP)

6 Conclusions

The S-map water content PTFs have been developed using available data from the National Soils Database to predict values for similar soils in other parts of New Zealand. Compared with actual measurements from the Wairau Valley, S-map predictions are accurate for wilting point but less so for field capacity.

The combination of field capacity and wilting point gives predictions for available water (AW) that are on average low for topsoil and slightly high for subsoil, with low correlation to measured values and high uncertainty on the very lowest AW values. AW predictions are better for subsoil than for topsoil, and better for Recent Soils than for Brown Soils. They also tend to be too high for high-sand and too low for high-clay content soils.

Following are some possible reasons for these results.

1 The development of S-map PTFs is restricted by the amount of measured soil data available for New Zealand, in terms of both the number of sites for different soil types and the number of soil properties measured at those sites.
2 Wairau Valley soils may not be well represented in the National Soils Database training data used for the PTFs.
3 The PTFs use a limited number of explanatory soil properties when predicting, so they are not able to capture the full variation of soils.
4 Wairau Valley topsoil samples were all taken from 0 to 7.5 cm of the functional horizon, whereas National Soils Database samples were generally taken at a depth that was representative of the whole horizon, typically taken as the horizon midpoint. The top of the topsoil is the most biologically active and is also subject to management effects, so its attributes are more variable than deeper in the topsoil. Further research may warrant separating the surface layer (0-10 cm) of topsoil functional horizons, into a separate functional horizon from the rest of the topsoil.
5 Laboratory analysis of soil properties will always have some degree of measurement error, due to the inherent difficulties in accurately measuring water content at different tensions, and may be the cause of some of the discrepancies between the measured and predicted values.
6 AW is derived from two individual water retention curve values, so its uncertainty is greater than for those values.
7 It can be difficult to correctly assess the soil properties that are inputs to the PTF (such as soil order and functional horizon coding) from the soil survey descriptions.

7 Recommendations

This analysis is based on a very limited data set over a very limited geographical area, so more general conclusions about the accuracy of the PTF cannot be drawn. It does, however, highlight the importance of extending the existing training data set for the PTF.

Some funding has been sought recently to retrieve and upload other legacy data sets into the National Soils Data Repository[7]. These data, along with newly sampled data collected under the MBIE-funded Next Generation S-map programme, will be used over the next few years to improve the PTFs. One aspect of this work will be to investigate the best way to handle topsoil samples taken from 0–7.5 cm, compared with samples taken a little lower in the topsoil horizon.

[7] A new version of the National Soils Database.

8 References

Hewitt AE 2010. New Zealand soil classification. 3rd edn. Lincoln, New Zealand, Manaaki Whenua Press.

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