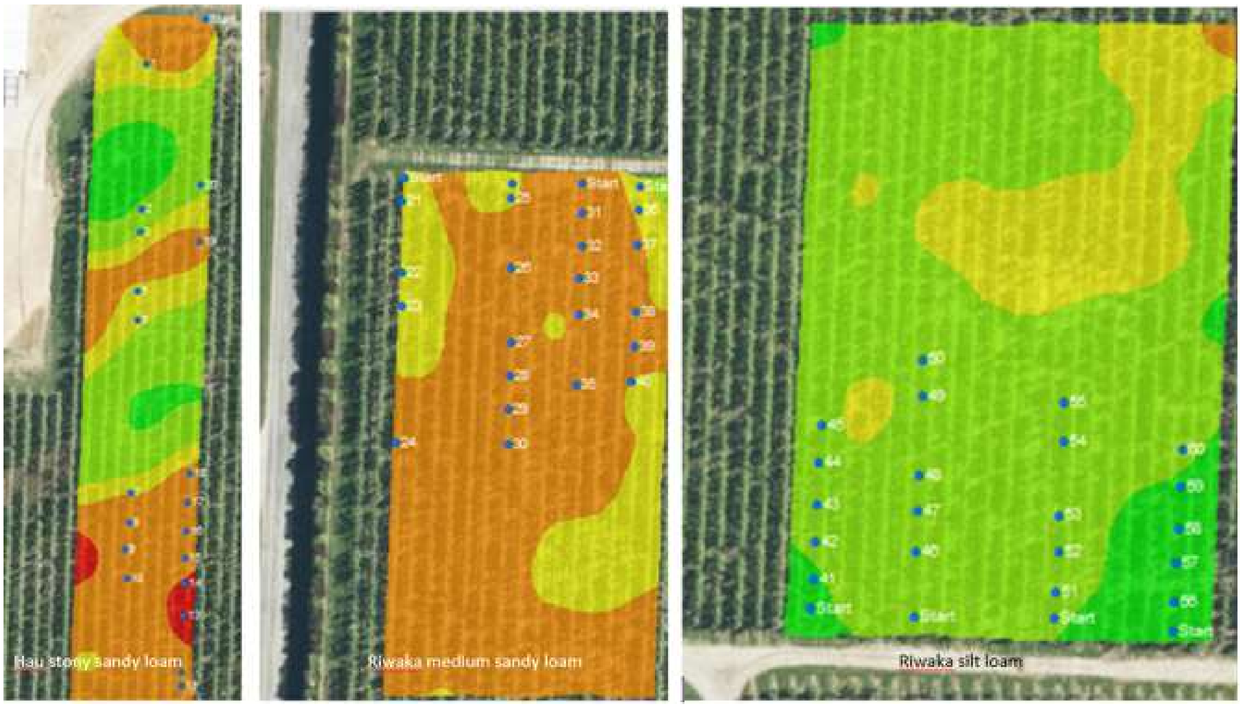
FRUITION
Horticulture



Research Report

What are the opportunities to reduce variability in apple tree productivity through targeted (sub-block) water and nutrient application*?*

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Executive Summary

Most of New Zealand's apple production occurs on soils which have formed from alluvial (river movement) deposits. These soils range from clays to sand, to gravels. As a result, orchard blocks can have considerable variation in soil composition and texture running through them.

This project was initiated to look at variation in an orchard block with varying soil textures, correlate the variation to soil texture, and consider if variable fertiliser and irrigation applications are warranted within the block.

Although there was large variation in soil texture and tree biomass between and within blocks, we could not confidently link soil texture with tree growth or productivity. However, trees on the Hau soil type were smaller, less vigorous and more productive. The inability to link soil texture with tree growth or productivity may be because orchard management tended to oversupply inputs to avoid areas of deficiency that might cause reduced productivity. Consequently, the concept of supplying variable fertiliser and irrigation applications within the block to mitigate soil texture based deficiencies is unlikely to have any positive effect on productivity under the current management practices. However, if management objectives were to shift towards minimizing inputs, a situation easily conceivable under improved ecological sustainability targets, application of nutrition or irrigation at a sub-block level, possibly based on soil texture, may become feasible and desirable.

Potential Future Research

1. Investigate NDVI values within and among seasons to understand their relationship with tree growth and yield.
2. Explore the use soil moisture deficit management using NDVI in conjunction with soil moisture monitoring.
3. Further explore the reasons for tree variability.

Introduction

This project investigated variability among apple trees in an orchard block with varying soil textures, to correlate tree variability with soil texture and consider if variable fertiliser and irrigation applications were warranted.

In Hawke's Bay and Tasman, most apple production occurs on soils that have formed from alluvial (river movement) deposits. These soils range from clays to sand to gravels from a wide range of parent material even within a defined soil type. Orchard blocks are usually laid out with only surface features in mind – roads, drains, boundaries, and little thought is given to soil features unless they are to be critically detrimental. As a result, orchard blocks can have considerable variation in soil composition and texture running through them while a uniform management strategy is applied to them.

Soil texture has a major influence in how much water a soil can hold and make available to plants over time. Soil texture also influences the amount of nutrient that can be temporarily stored for plant use, particularly the cations e.g. potassium, calcium and magnesium. It is well documented that soils with light texture need smaller amounts of nutrient and water, applied more often, compared with heavier textured soils. Current industry practices is that orchards are generally managed at a block level without regard to soil texture variation within them. There is no accounting for the considerable variation in tree requirements due to variability in soil texture. As world leaders in the move to higher production levels, New Zealand orchardists have become better at solving the more obvious yield limiting factors at a block level. However, improving yield and quality further will require understanding and reducing sub-block and tree level variation. In addition, block-level irrigation and fertilisation can be wasteful of resources – some plants are oversupplied while others are undersupplied and can also result in pollution to aquifers and water ways.

Reducing between-tree variation also has the potential to achieve more even fruit maturity and quality, which is also important for the economics of mechanisation and post-harvest outturn.

The objectives of this work were as a first step in determining:

1. the effect of variable soil texture on tree variability
2. implication of soil texture on yield
3. the cost/benefit of implementing a strategy to reduce tree variability.

Methods

Study design

The block selected for this study was owned by Kono Horticulture (188 College Street, Motueka, 7120) on the corner of Chamberlain and College Street, Motueka. Running through the block were four soil types having different soil textures (Figure 1). Three soil types were selected for the study; Hau stony sandy loam, Riwaka medium sandy loam and Riwaka silt loam, to give a arrange of soil textures. All trees were the cultivar 'Scilate' (Envy^{TM}) on 'M9' rootstock planted in 2010.

The greater 23 ha apple block was irrigation sectored into smaller blocks to account for the broadly different soil types and irrigation design requirements, and separately managed in terms of irrigation scheduling with four soil moisture monitoring sites. However, it was assumed that there would be variation in soil texture within these soil types.

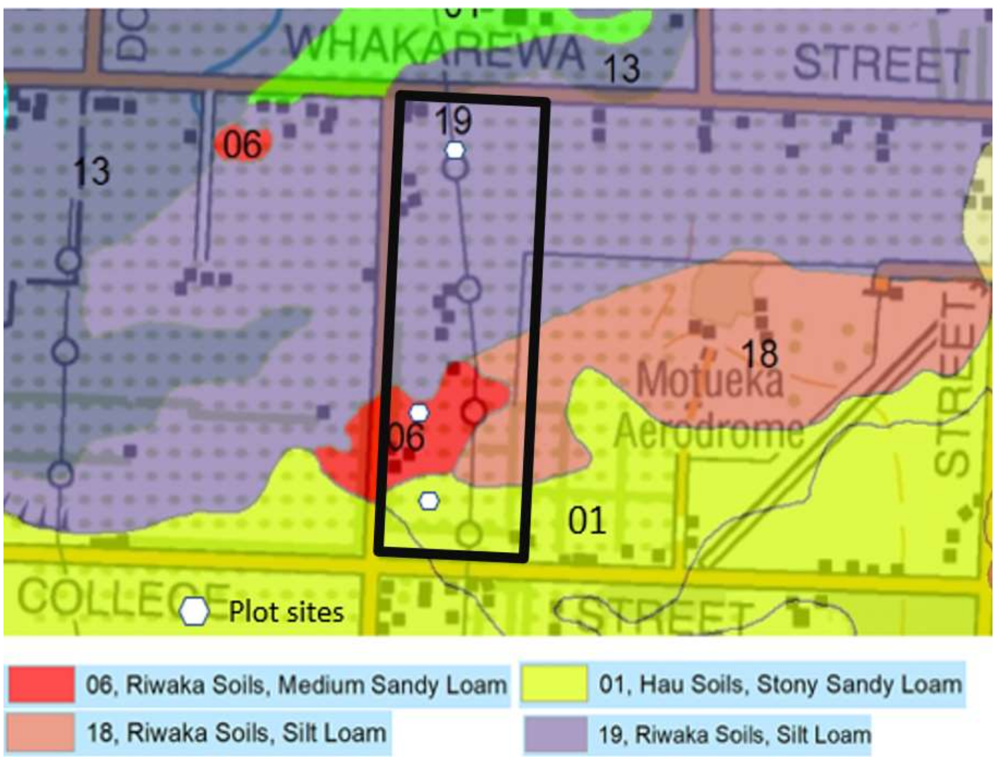


Figure 1: Within each of three soil types 20 plots of 62 m^2 each were selected.

On each of the three soil types, 20 plots were selected randomly (avoiding any excessively low areas) and marked out avoiding any excessively low areas. Each plot consisted of a bay between 2 posts containing 7 trees in three adjacent rows, a total of 21 adjacent trees. This represented a surface area of 62 m^2 (tree spacing 3.3m x 0.9m). Where possible, data were recorded from all 21 trees in each block, however replanted trees and pollinisers were not included.

Soil moisture levels were monitored using Sentek continuous monitoring probes (capacitance sensors) to 90cm on one site, on each soil type.

Measurements

Trunk size

Trunk cross-sectional area is a reasonable indicator of total tree biomass in blocks of this age and variations in size an indicator of historical variation within a block. Trunk circumference was measured on each tree 20cm above the graft union and converted to trunk cross-sectional area (TCA).

Soil texture

Eight to ten soil cores to a depth of 15cm were taken from each plot and homogenized to provide one soil sample per block. Samples were air dried and then passed through a 2mm sieve. Soil texture was then determined for each sample using accepted methodology by fractionating the sand, silt and clay particles through dispersing these components in water. A portion of soil was mixed with water and 5ml of powdered detergent and agitated for 10 minutes to break down particle bonds. Flasks were then allowed to stand. Sand, silt then clay particles settled out into distinct bands and the width of each band was then recorded (Figure 2).

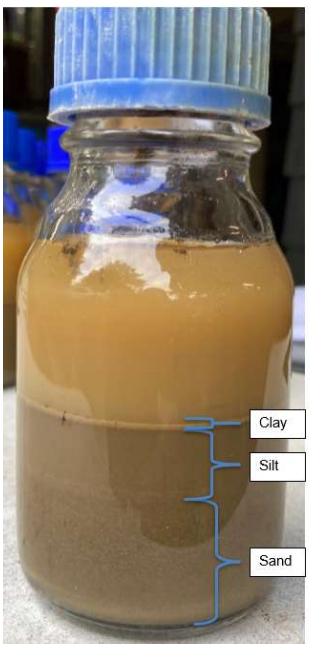


Figure 2: Soil sample with s and, silt andclay fractions

Figure 3: Measuring tree trunk *circumference to calculate* cross-sectional area

Soil chemical properties

From each of ten plots, homogenized soil samples from each soil type were chemically analyzed at Hill Laboratories (Private Bag 3205, Hamilton, 3240).

Yield data

The block was extensively damaged in a hail event on 26/12/2020. Management was then undertaken for tree recovery rather than fruit production, with subsequent large variations in crop load on trees. Consequently, there was little merit in undertaking fruit harvest measurements. Instead, potential fruiting load was assessed by measuring branch basal circumference and converting this to branch cross-sectional area (BCA) on seven to ten trees within each plot. In this block, a fruit load of 5 fruit per cm^2 BCA gives a potential number of fruit that that branch (or tree if the branch BCAs are summed) can effectively support to harvest size.

Normalized Difference Vegetation Index (NDVI) mapping

NDVI mapping uses satellite imagery to measures near-infrared light reflectance (Figure 4). It can provide an accurate indication of the presence of chlorophyll, which, with accurate interpretation, correlates with plant 'health' and vigour. Imagery was obtained from 9/02/2021. Data was georeferenced to a 50cm grid. Mean values were calculated from points within a 2.5m radius from the centre of each plot.

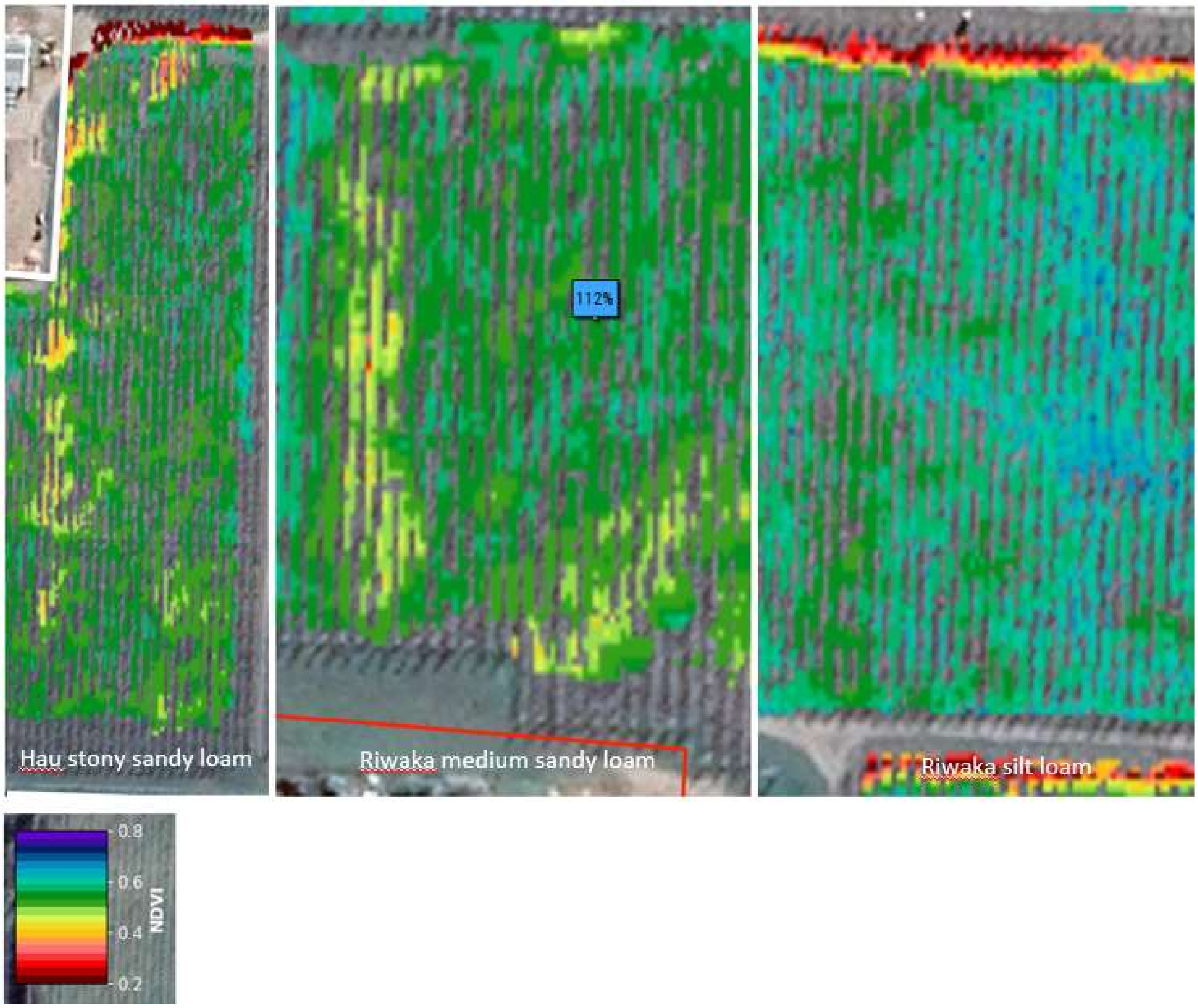


Figure 4: Image of NVDI variation within each of the soil type areas, Yellow through to red has a lower NVDI index value showing lower chlorophyll levels which may indicate stress or reduced vigor, with green through to blue showing a larger index value showing high chlorophyll levels which indicate active photosynthesis and less stress.

Electromagnetic (EM) mapping

An electromagnetic soil survey was conducted over the study areas (Figure 5). This involves using a magnetic field to measure soil conductivity. Coarse soil texture such as sand has a low conductivity compared with a soil having a higher proportion of clay, which has a high conductivity and a silt soil having a medium conductivity. Measurements were taken at two depths (0.4m, 1.2-1.4m) and mean values for each plot were derived from a 3m radius from the plot centre.

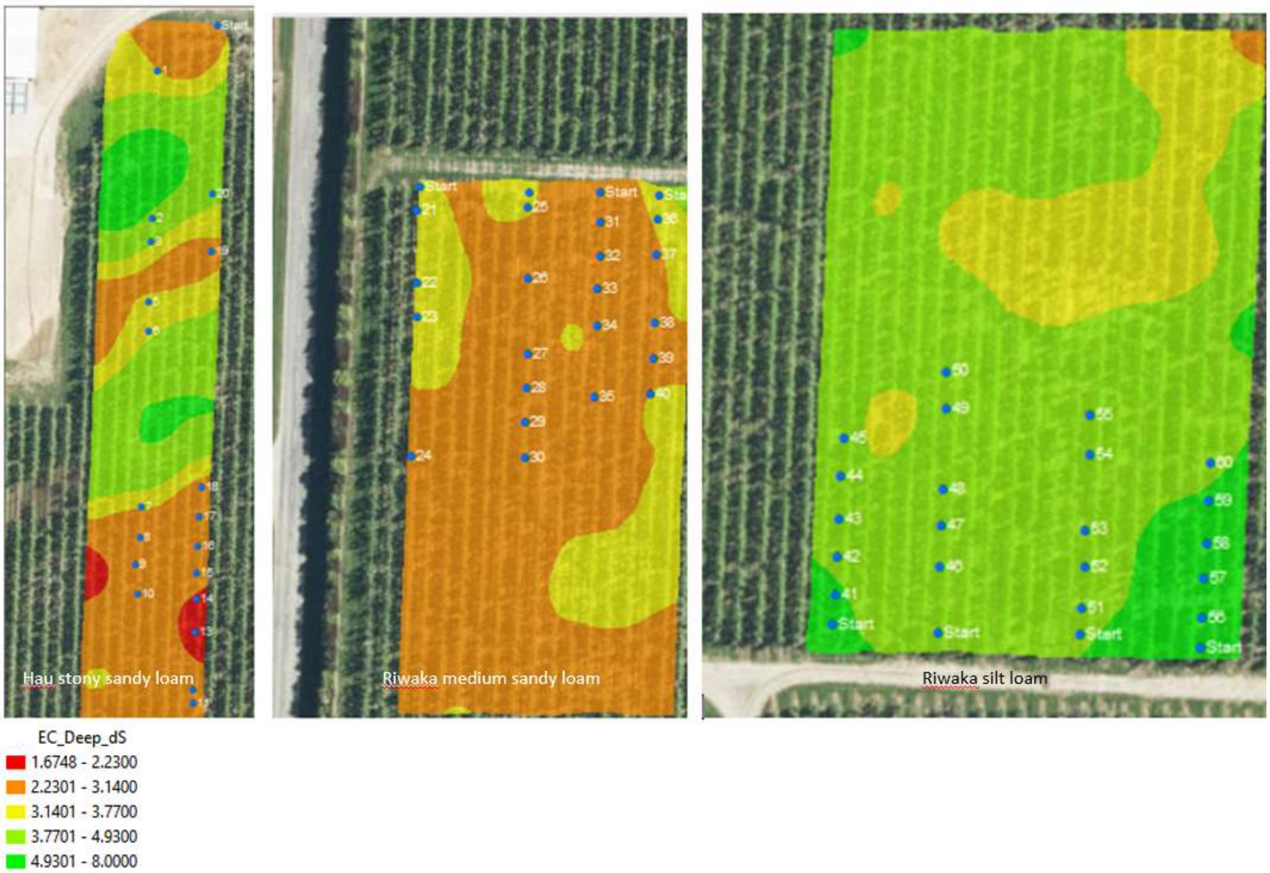


Figure 5: Image of Electromagnetic survey mapping of each soil type at the 1.2 to 1.4 metre depth. The smaller the electrical conductivity (EC) value the coarser the base material. Red brown and yellows would be prograding gravels (red - bigger gravels, yellow smaller), the light green likely sands, and the darker greens sandy to silty.

Results

Chemical Analysis

Chemical analysis of the soil types are shown in Figure 6. Main differences between soil types are:

1. In many cases there was greater variability within a soil that among soils (The range of values either side of the median for a soil varied more widely than the medians of the soils).
2. Higher levels of calcium and magnesium were found in the Riwaka silt loam soil compared with the sandy loam types.
3. There was high variability in pH and Olsen P levels, with the Riwaka medium sandy loam showing higher levels of both.
4. Anion storage capacity was relatively low (mean levels 14 – 16%) for all three soil types, with more variation within the Hau stony sandy loam type.
5. Cation exchange capacity was fairly low for all the soil types with the Riwaka sandy loam having 15% compared to 12% for the Hau and the Riwaka medium sandy loam.

Overall, it is considered that there was little difference in nutrient supply among the soil types and all samples were generally within sufficiency levels for apple production.

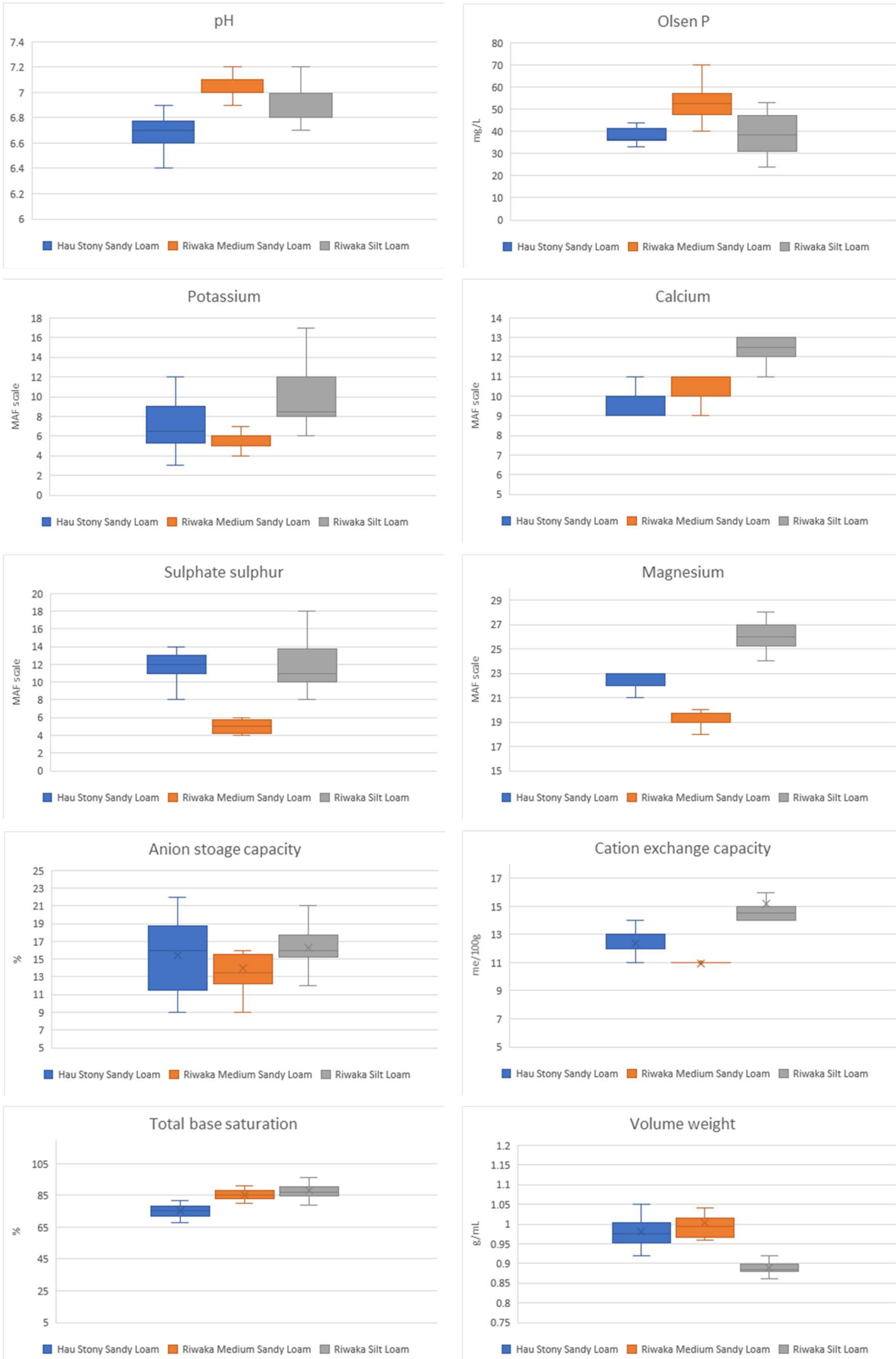


Figure 6: Soil analysis results from 10 plots (locations) within each soil type.

Soil Texture

All three soil types consisted mostly of sand and silt components with very little clay found in any of the plots. This left the proportion of sand to silt as the main influence on soil texture. The greater proportion of sand in a sample makes a lighter texture soil with less water holding capacity and less ability to retain nutrients. Although there were observed differences in the sand fraction among soils (Figure 7), as was shown in the chemical analysis, variability among samples was as large or larger than variability among soils. However, as would be expected the Riwaka silt loam generally had less proportion of sand particles and was of a heavier texture.

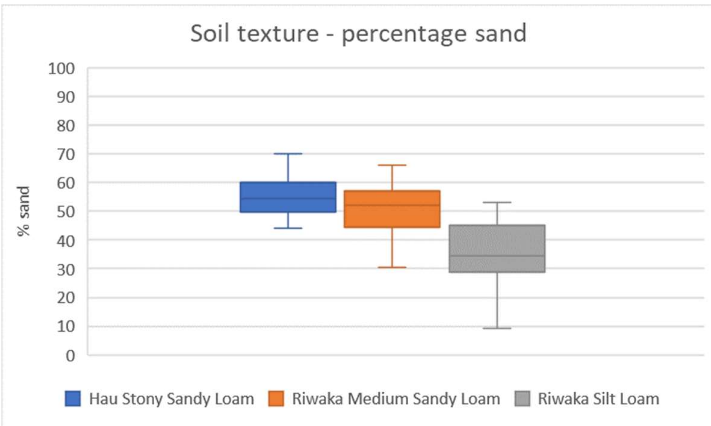


Figure 7: Mean percentage of sand (as an indicator of texture) by soil type

Tree Growth

Mean tree biomass represented by TCA, was significantly less for trees grown on the Hau stony sandy loam (27 cm^2) compared with 41 cm^2 and 39 cm^2 for the Riwaka medium sandy loam and the Riwaka silt loam respectively (Figure 8). Trees on the Hau stony sandy loam also had smaller branches, with a mean BCA of 2.5 cm^2, compared with 3.3 and 2.7 for the Riwaka medium sandy loam and the Riwaka silt loam respectively.

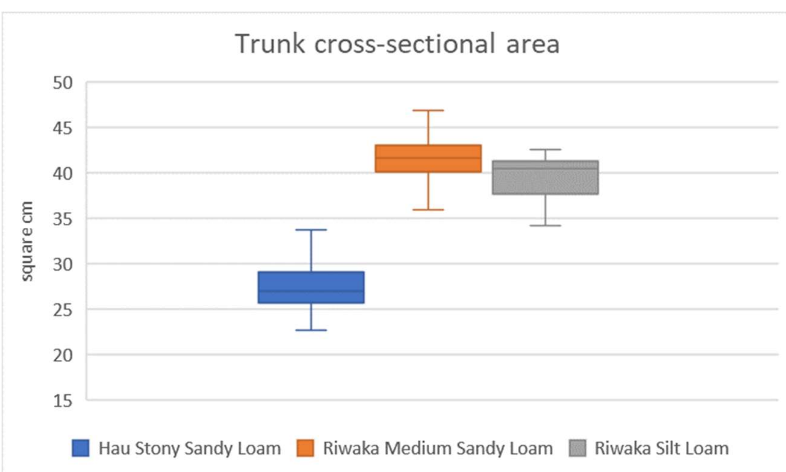


Figure 8: Mean trunk cross-sectional area in cm^2 by soil type

Figure 9: Hau stony sandy loam

Figure 10: Riwaka silt loam

Figure 11: Hau stony sandy loam

Figure 12: Riwaka silt loam

Electromagnetic Survey

The electromagnetic (EM) survey did not detect differences in localised soil textures within a soil type that may explain soil texture (percent sand) variation either at the shallow 0.4 metre or at 1.4 metre depth (Figures 13 and 14)

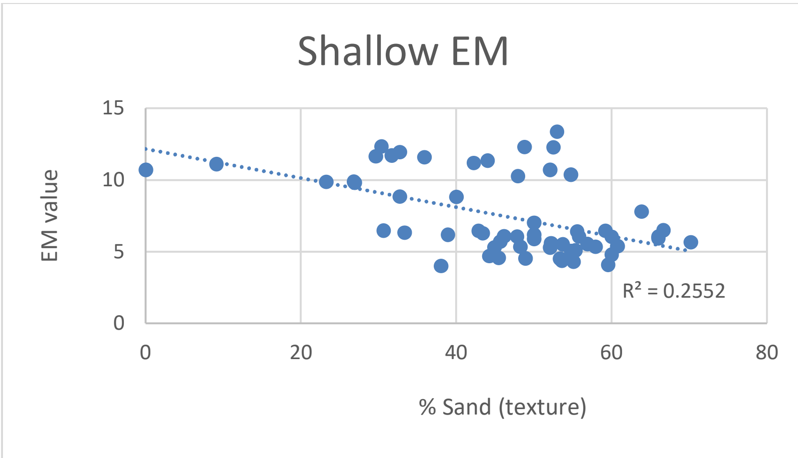


Figure 13: Mean percentage sand of a plot compared to shallow EM value

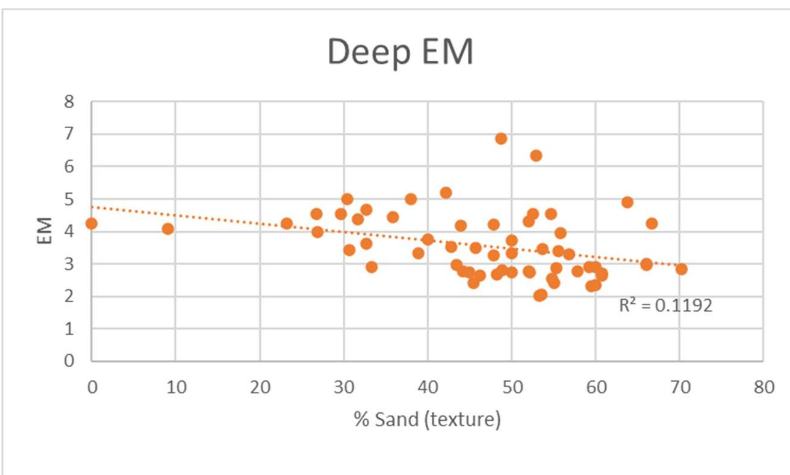


Figure 14: Mean percentage sand of a plot compared to deep EM value

Production levels for the 2018-2020 seasons are given in Figure 15. Over three seasons, production on the light textured Hau stony sandy loam was higher at 280t/ha compared with 234 and 207 t/ha on the other two soil types that had greater tree biomass.

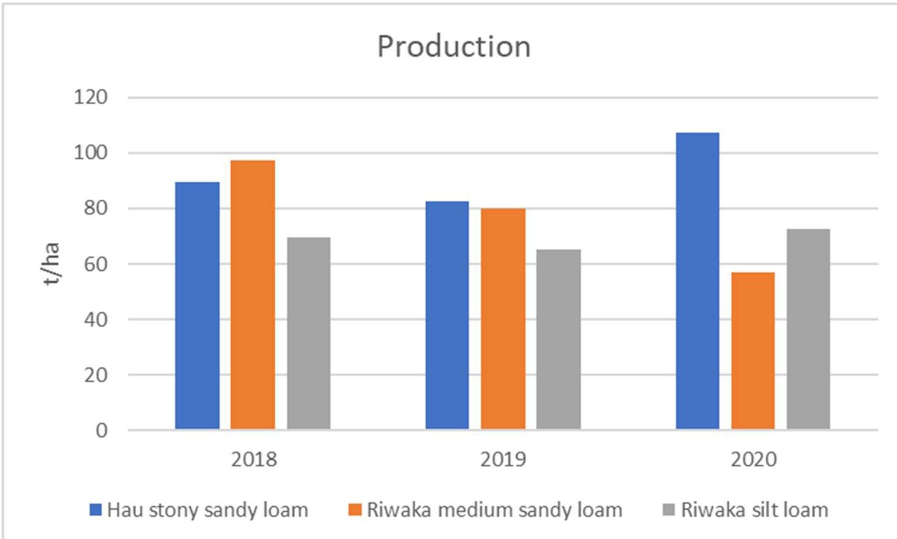


Figure 15: Production levels in t/ha from blocks within each of the soil types

NDVI

NDVI images taken on 9 February (Figure 16) strongly correlated (R^2 0.79) to tree TCA. Plants with a high NDVI value in the February period had developed larger trunk area over time.

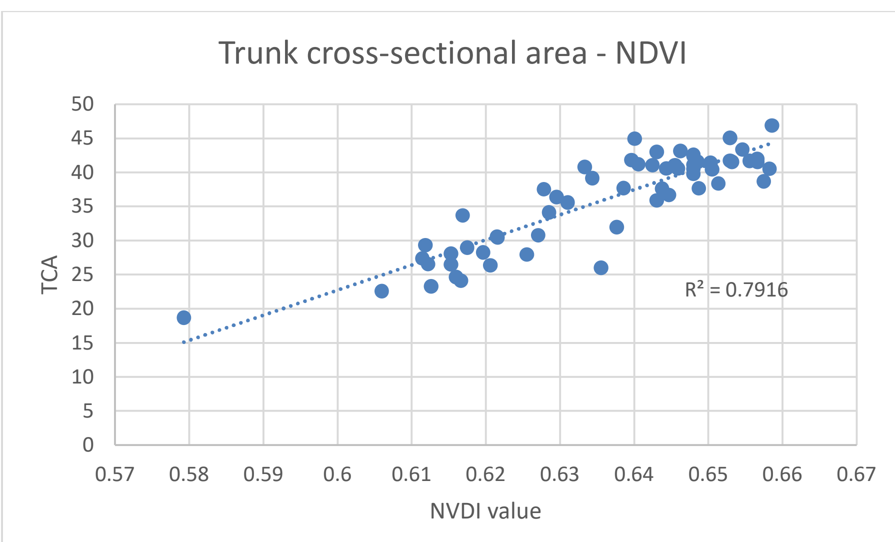


Figure 16 Relationship of tree biomass (TCA) and NDVI values taken on 9/2/2021.

Discussion

Growers aim to apply water and nutrients at levels that are sufficient to support plant and fruit growth and development. The rates of nutrient applied are dependent on soil test results, previous seasons leaf tissue test results and plant performance at a whole block level, and do not take into account within block variability. Consequently, there will be areas of oversupply of nutrient, particularly as growers prefer to avoid undersupply.

In this research, soil tests showed that nutrition was generally not limiting at either a block or sub-block (plot) level. However, for example, the soil test survey of 10 plots per soil type indicated that there was significant variation in in Olsen P results in both the Riwaka medium sandy soil and the Riwaka silt loam soil, while the Hau stony sandy loam had low variability. This suggests that there is opportunity to reduce inputs by a more targeted, sub-block application of phosphorus. Similar opportunities may be available with other elements such as potassium. However, this could not be determined or correlated to any of the variables measured such as soil texture, so would depend on more cost-effective soil chemical analysis processes than what is currently available.

In the case of irrigation, seasonal traces of soil moisture content showed that soil moisture was not limiting at block level and there was strong indication that irrigation frequency could be reduced in both the Hau stony sandy loam and Riwaka medium sandy loam soils (Appendix). However, with only a single monitoring station per block, we were unable to interpret this at a plot level. Given that results showed greater variability in texture among plots than among soils, opportunities may exist to save inputs through more targeted application at sub-block level, but because measurement of soil moisture at a plot level was outside of the scope of this work, this should be included in a subsequent study. A more intensive project measuring NDVI scores throughout the season may be warranted and yield more insight to tree performance to soil texture/soil moisture dynamics.

Interpretation of the NDVI data was limited because overhead satellite frequency and cloud cover restricted the number of successful images received. The strong ($R^2 = 0.79$) positive correlation between NDVI and tree biomass may not so much show that trees with lower biomass were less ‘healthy’ or under stress, but that those trees were less vigorous. High vigor, and dark green leaves in the mid- to late-season, at the stage that the NDVI imagery was taken is usually an indicator of excess vigor. In trees with excess vigor, post-harvest fruit quality is reduced and high leaf area may cause shading, reducing marketable yield through reduced fruit colour. Examination of the trees across the plots suggested the smaller trees (TCA and BCA) with lower NDVI scores observed in the Hau stony sandy loam soil were likely to be better performing trees; an observation supported by yield data. This also suggests that there is opportunity to improve productivity by reducing inputs at a block level. Given the wide variation in soil texture as measured by percentage of sand, there may also be opportunity to improve productivity by managing inputs at a sub-block level.

The large differences in tree biomass could not be explained by soil texture either through the sample fraction method or the EM survey, despite the wide differences in soil texture within and among the soil types. It is possible that the tendency of growers to liberally supply inputs so as to avoid areas of deficiency may have clouded this relationship.

In conclusion, it was not possible to confidently link soil type or texture and tree growth or productivity. This may be because orchard management tended to oversupply inputs to avoid areas of deficiency that might cause reduced productivity. A number of factors investigated at both the block- and a sub-block (plot) level supported this view. Consequently, the original concept of supplying a secondary irrigation line to mitigate soil texture based moisture deficiencies is unlikely to have any positive effect on productivity under the current management practices. However, if management objectives were to shift towards minimizing inputs, a situation easily conceivable under improved ecological sustainability targets, application of nutrition or irrigation at a sub-block level, possibly based on soil texture, may become feasible and desirable.

Supplementary irrigation system

The original concept of this study, assuming that there were significant texture variations within a block, was to review the cost/benefit of a secondary trickle irrigation line down each row to offer the ability to have a 2-tier irrigation delivery system. This would give the flexibility to irrigate the major portions of area to one regime while having the ability to water lighter textured areas under a less but more often irrigation schedule. This would cost in plant and equipment $5,564 /Ha to install.

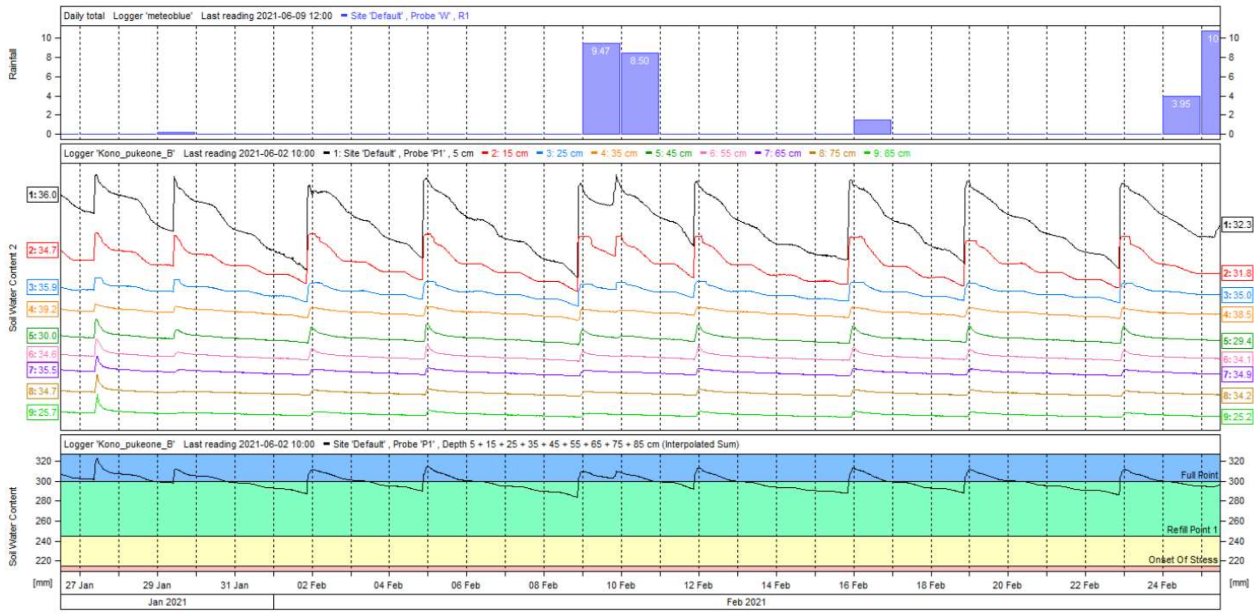
Sarah Binns		Twin irrigation		Net 20th after EOM		13/05/2021	Page 1
QTY	ITEM NO	DESCRIPTION	PRICE	UNIT	DISC	EXTENDED PRICE	GST
15	LD16.200HIPOL	LDPE Black 16mm x 200m - 500kP	$159.00	ea	10%	$2,146.50	S15
25	GTO1916	Driploc Take Off 16mm c/w Grom	$2.98	ea	10%	$67.05	S15
1	LD16.50HIPOL	LDPE Black 16mm x 50m - 500kPa	$39.75	ea	10%	$35.78	S15
75	DLRJ1616DB	Dripline 16mm x 16mm Lateral J	$0.58	ea	10%	$39.15	S15
25	DLES16	Dripline End Sleeve 16mm	$0.30	ea	10%	$6.75	S15
.75	LD50.100	LDPE Black 50mm x 100m - 72psi	$458.78	ea	10%	$309.68	S15
1	HB50	50MM BEND	$44.94	ea	15%	$38.20	S15
1	HMS50	50MM MALE STRAIGHT COUPLING	$21.16	ea	15%	$17.99	S15
1	RXC/W50	RX 50mm Cap & Washer	$4.65	ea	10%	$4.18	S15
6	IRRI02	IrriClip #2 16-24mm 1000/Bag	$154.00	ea	15%	$785.40	S15
.5	210-050A-P	200 Series Valve 50mm - Angle	$244.00	ea		$122.00	S15
1	804-50	PVC Plain Tee 50mm	$10.50	ea		$10.50	S15
2	801-50-90	PVC Plain Elbow 50mm 90*	$7.47	ea		$14.94	S15
2	813-50	PVC Valve Socket 50 x 50mm BSP	$8.07	ea		$16.14	S15
.5	800.50PN9.6	50mm PVC Pipe PN9 x 6m SOE	$75.07	LGN		$37.54	S15
100	IC215-500mtr	IrrigationCable2 Core 1.5mm/mt	$2.21	mtr	10%	$198.90	S15
4	CON3WAY	3M Gel Connector - 3 Way	$3.37	EA		$13.48	S15
5	Digger Yanmar	CWS Yanmar Digger 1.7T Hire	$40.00	hr		$200.00	S15
60	Labour	Labour	$25.00			$1,500.00	S15

Figure 17: Cost of establishing a second trickle line /Ha

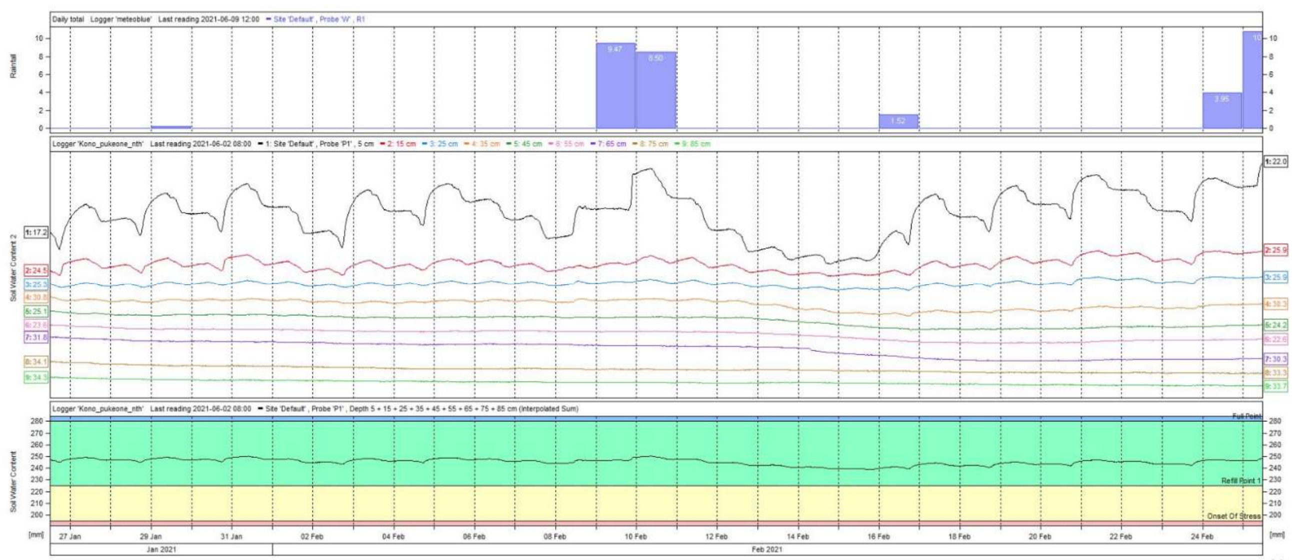
Potential Future Research

4. Investigate NDVI values within and among seasons to understand their relationship with tree growth and yield.
5. Explore the use soil moisture deficit management using NDVI in conjunction with soil moisture monitoring.
6. Further explore the reasons for tree variability.

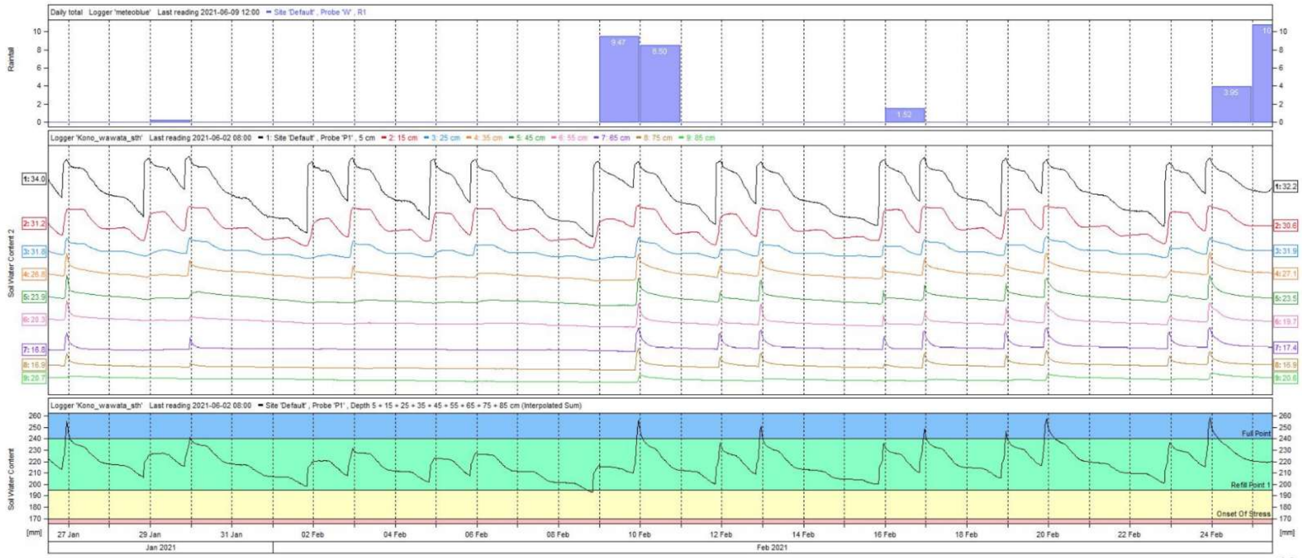
Appendix



Late season soil moisture levels Hau stony sandy loam



Late season soil moisture levels Riwaka medium sandy loam



Late season soil moisture levels Riwaka silt loam

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