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MEASUREMENT OF SOIL NUTRIENTS UNDER GREEN FEED CROPS IN AN INTENSIVE DAIRY SUPPORT OPERATION

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Abstract

Basic understanding of fundamental nutrient dynamics in crops and soils is prudent in mitigating risk of nutrient losses. Some of the free draining gravelly soils in Canterbury have been referred to as "leaky Lismores" in terms of their supposedly poor nutrient holding ability. Hence there is now a real need for strategic nutrient management in order to optimise crop yield and mitigate any risk of nutrient losses. This is also closely allied to various perceptions of the mandatory obligations on growers to conform to the received environmental standards. Growers are also mindful of the economic imperative to maintain a financially viable farming business, whilst simultaneously improving yield and showing environmental compliance.

Because the ultimate measure of Nutrient Use Efficiency (NUE) and Water Use Efficiency (WUE) is yield (as kg/ha of Dry Matter produced per mm of water and kg of nutrient applied) then to show increased NUE and WUE, yield must go up. As yield approaches the economic threshold, WUE and NUE will also be approaching optimum, i.e. yield will be nearing full potential at the point where NUE and WUE is also at, or very near to, the agronomic and economic optimum.

The perception that increased yield leads to increased nutrient loss and hence reduced water quality is not a safe assumption. The information gained in this investigation clearly demonstrates that it is possible to mitigate nutrient losses with good management of irrigation and fertiliser inputs.

Soil tests from the site investigated show that soil nutrients remaining after the second green feed crop (kale following beet); as well as the additional barn effluent applied; are retained within the root zone of the crop after successive drainage events. These nutrients are then available to be utilised by current and subsequent crops. Actual real time measurement with capacitance probes and accurate soil testing is able to affirm that appropriate nutrient management strategies can be successfully employed. This approach also has the added advantage of giving growers confidence to continue to improve NUE and WUE along with the yield of the crops they grow, knowing that there is robust technology available to demonstrate that they can measure NUE and WUE and also provide objective proof of good practice and environmental stewardship.

Introduction

Lismore soil is typified by 60 % stones in the top 300 mm cultivated layer, another 300mm B horizon of gravels in a silty matrix, and free running sandy shingle below. From S-Maps, plant available water capacity (PAWC) is 75mm. These soil types have occasionally been referred to as “leaky” by various industry commentators. Therefore, a good understanding of nutrient dynamics in a stony Lismore sandy silt loam is prudent in order to objectively mitigate any perceived risk of nutrient losses to ground water. Soil texture is clearly shown in the jar test opposite (Figure 1) with the sieved and flocculated soil sample typical of the site, showing approx. 10 % clay (thin pale layer on top)); 45% silt and 45% sand.

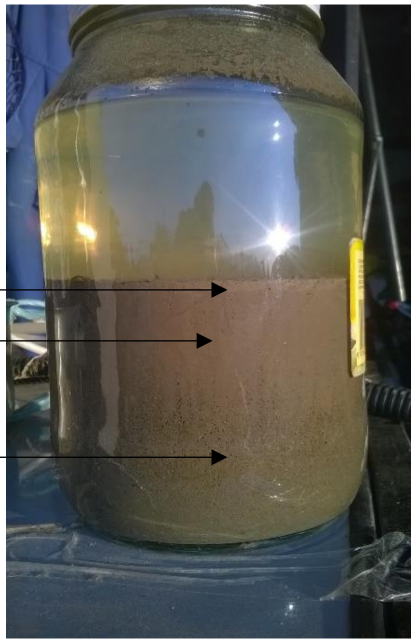

Figure 1: Soil texture jar test.

The need for improved refinement and greater understanding of strategic nutrient management is also closely allied to various perceptions of the mandatory obligations on growers to conform to the received environmental standards, and the economic imperative to maintain a financially viable (and thus sustainable) farming business simultaneously.

With the advent of frequency domain reflectometry soil probes capable of providing real time data on soil moisture content and nutrient movement, along with the observed presence of significant root mass at depths well below the cultivated layer, this investigation has been able to obtain hard data on what is actually visibly happening under the crops and soils in question. This provides verification of the information generated by the Sentek probe by using soil testing at different depths down the profile within the soil column that is being measured.

Materials and Methods

Following preliminary investigations of hand dug pits down to 600 mm in the spring of cropping season 2013-14; a series of deep soil inspection pits was excavated with a hydraulic digger to enable accurate appraisal of rooting depth of a fodder beet crop at Stonehaven, property of DW & R Keeley, 1070 Maronan Ealing Road, near Mayfield in Mid Canterbury.
This information was required to inform irrigation and nutrient management decisions for future crops of winter green feed kale, and also other crops in the rotation, such as ryegrass, cereals and maize.

The fodder beet crop which preceded the kale in this investigation had well developed visible active, healthy root mass, down to 700 mm depth at the time of inspection. This beet crop was also seen to be utilising soil moisture at this depth as shown by the concurrent readings from the nearby Sentek probe. This probe remotely measures soil moisture content and nutrient concentration in the soil solution and sends this information directly to a smart phone or other internet connected device. This technology enables real time remote management of water applied with irrigation and enables accurate deployment of "deficit irrigation" techniques to optimise WUE.

Figure 2. Fodder beet rooting depth.

In the following season, the fodder beet site shown above (Figure 2.) was sown to green feed kale (see Figure 3. below).

Figure 3. Green feed kale.

At the completion of the grazing of the kale (Fig 3) in the spring of 2015, an earth bund of approximately 1 m^2 in area was constructed to encompass the probe. Barn liquor was then loaded into the bunded area around the probe at the rate of 60 litres/day for 8 days. The concurrent spikes in VIC and soil moisture drainage through the profile are clearly visible on the graphs from the probe at that time. (see Figs. 6,7& 8). Nitrogen applied as effluent at this time was equivalent to 2544 kg/ha. No evidence of nutrient percolation below the root zone was observed from the probe read out (Figure 7.) or the subsequent soil testing.

Figure 4.Effluent applied to probe 2nd – 10th October 2015

Sample Type: Aqueous						
Sample Name:		Keeley 02-Sep-2015 5:00 pm				
Lab Number:		1471230.1				
Farm Effluent Samples						
Total Nitrogen*	kg/m³	0.53	-	-	-	-
Total Phosphorus*	kg/m³	0.065	-	-	-	-
Total Potassium*	kg/m³	0.26	-	-	-	-
Total Calcium*	kg/m³	0.154	-	-	-	-
Total Magnesium*	kg/m³	0.041	-	-	-	-
Total Sodium*	kg/m³	0.040	-	-	-	-
Total Sulphur*	kg/m³	< 0.3	-	-	-	-
NPK applied for a 10 mm application depth						
Nitrogen applied*	kg/ha	53	-	-	-	-
Phosphorus applied*	kg/ha	6.5	-	-	-	-
Potassium applied*	kg/ha	26	-	-	-	-
NPK applied for a 20 mm application depth						
Nitrogen applied*	kg/ha	105	-	-	-	-
Phosphorus applied*	kg/ha	13.1	-	-	-	-
Potassium applied*	kg/ha	52	-	-	-	-

Figure 5. Effluent analysis report

Results

Throughout the life of the kale crop, the Sentek probe showed that VIC did not fluctuate significantly below 600 mm depth and remained static at 1000 mm depth. However, during rainfall events such as the one in mid-winter of 2015, soil moisture was on one occasion seen to be draining through the profile beyond the 1000 mm depth of the probe in the third week of June.

The following graphs (Figures 6., 7. & 8.) from the probe show the changes in VIC and soil moisture at different depths down the profile.

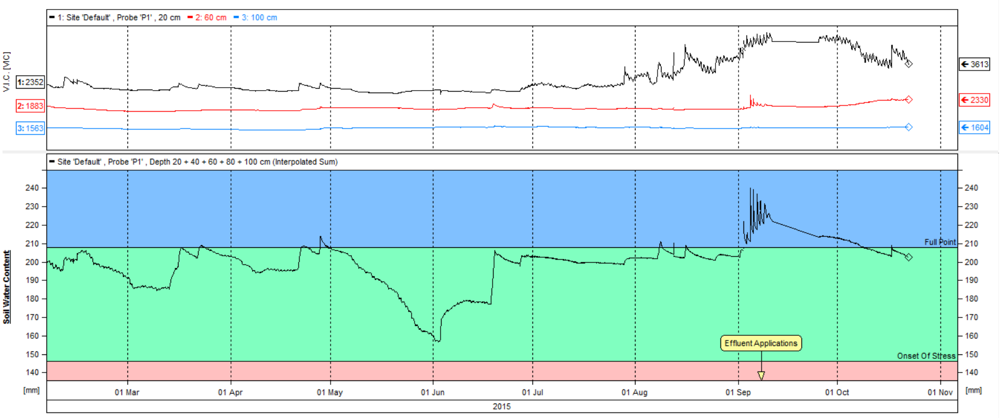

Figure 6. March to November VIC & SMC combined totals with AWC in green band.

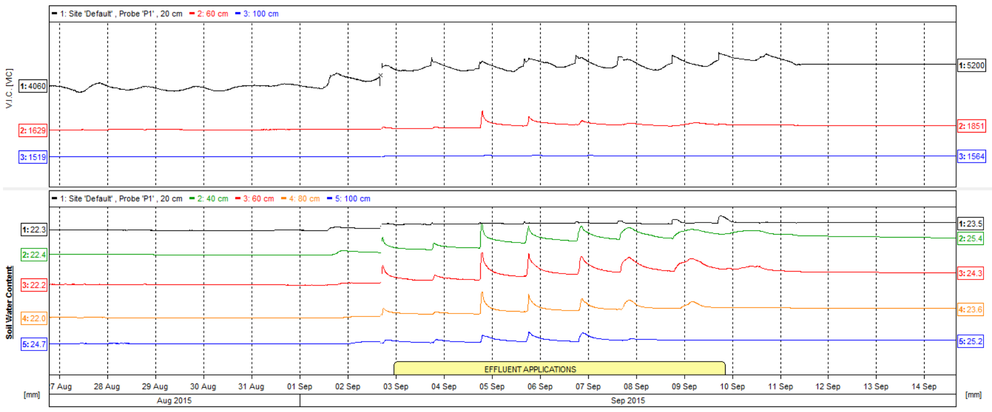

Figure 7. VIC at 3 depths & SMC at 5 depths with daily effluent applications.

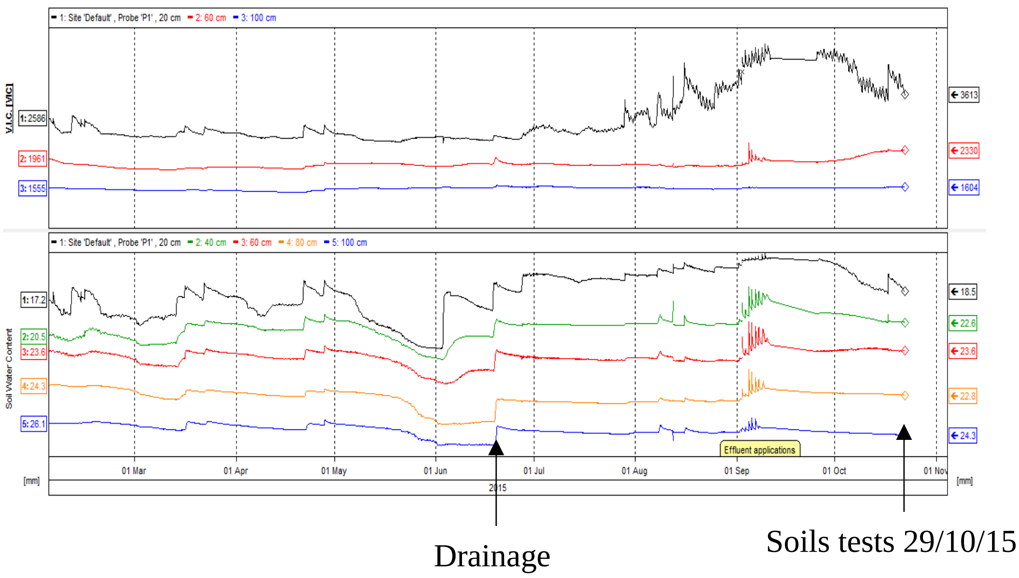

Figure 8. VIC depths with SMC at 5 depths March to November 2015.

Inspection of another deep pit (Figure 9.), again showed that the Kale crop had roots visible down to 1700 mm depth in February (canopy climax). The probe had again recorded very small and infrequent soil moisture drainage events. Again, no evidence of nutrient movement below 1000 mm was recorded by the probe. Concurrent analysis of soil samples at the 1500 – 1800 mm depth gave very low levels of all plant nutrients under the actively growing crop prior to winter grazing. (Results shown in Figure 10. below).

An additional series of deep inspection pits were also excavated throughout the wider Mid-Canterbury area in February of 2015 to enable comparisons across a range of soil types and sites under various crops. This included process potatoes, process carrots, forage maize, grazed ryegrass aftermath at Stonehaven, and also the green feed Kale discussed in this report.

Figure 9. Gravelly sandy subsoil showing deeper root systems of kale.

Sample Name: Pdk #1 G/F Kale — **Lab Number:** 1426186.2
Sample Type: SOIL General, Horticulture (S9)

Analysis		Level Found	Medium Range
pH	pH Units	6.0	5.8 - 6.5
Olsen Phosphorus	mg/L	7	25 - 50
Potassium	me/100g	0.05	0.50 - 1.00
Calcium	me/100g	0.6	6.0 - 12.0
Magnesium	me/100g	0.07	1.00 - 3.00
Sodium	me/100g	< 0.05	0.00 - 0.50
Potassium	%BS	1.7	3.0 - 6.0
Calcium	%BS	19	50 - 75
Magnesium	%BS	2.2	7.0 - 15.0
Sodium	%BS	1.0	1.0 - 2.0
CEC	me/100g	3	12 - 25
Total Base Saturation	%	24	60 - 85
Volume Weight	g/mL	1.47	0.60 - 1.00
Sulphate Sulphur	mg/kg	3	10 - 20
Available Nitrogen (15cm Depth)*	kg/ha	< 10	100 - 150
Anaerobically Mineralisable N*	µg/g	< 5	
Organic Matter*	%	0.9	7.0 - 17.0
Total Carbon*	%	0.5	
Total Nitrogen*	%	0.05	0.30 - 0.60
C/N Ratio*		10.4	
Anaerobically Mineralisable N/Total N Ratio*	%	< 0.5	3.0 - 5.0
Soil Sample Depth*	mm	0-1000	
MAF Units		K 2 Ca 1	Mg 2 Na 2

Figure 10. Deep pit soil test results from this kale paddock in February 2015.

Figures 10. and 11. were both tested under the same weather conditions at the same time. This demonstrates that nutrients at depth are also low under different crops and management.

Figure 11. (below) was from ryegrass located immediately adjacent to the green feed kale. Soil analysis from the lower levels immediately below the root zones of this crop also gave very low levels of plant nutrients on the Lismore soils as shown below in Figures 11. and 12.

Sample Name: Pdk 12 Ryegrass | **Lab Number:** 1426186.1
Sample Type: SOIL General, Horticulture (S9)

Analysis		Level Found	Medium Range
pH	pH Units	6.1	5.8 - 6.5
Olsen Phosphorus	mg/L	7	25 - 50
Potassium	me/100g	0.09	0.50 - 1.00
Calcium	me/100g	0.5	6.0 - 12.0
Magnesium	me/100g	0.06	1.00 - 3.00
Sodium	me/100g	< 0.05	0.00 - 0.50
Potassium	%BS	3.4	3.0 - 6.0
Calcium	%BS	19	50 - 75
Magnesium	%BS	2.2	7.0 - 15.0
Sodium	%BS	1.4	1.0 - 2.0
CEC	me/100g	3	12 - 25
Total Base Saturation	%	26	60 - 85
Volume Weight	g/mL	1.46	0.60 - 1.00
Sulphate Sulphur	mg/kg	7	10 - 20
Available Nitrogen (15cm Depth)*	kg/ha	10	100 - 150
Anaerobically Mineralisable N*	µg/g	< 5	
Organic Matter*	%	1.0	7.0 - 17.0
Total Carbon*	%	0.6	
Total Nitrogen*	%	< 0.04	0.30 - 0.60
C/N Ratio*		14.9	
Anaerobically Mineralisable N/Total N Ratio*	%	1.2	3.0 - 5.0
Soil Sample Depth*	mm	0-1000	
MAF Units		K 3 Ca < 1	Mg 2 Na 3

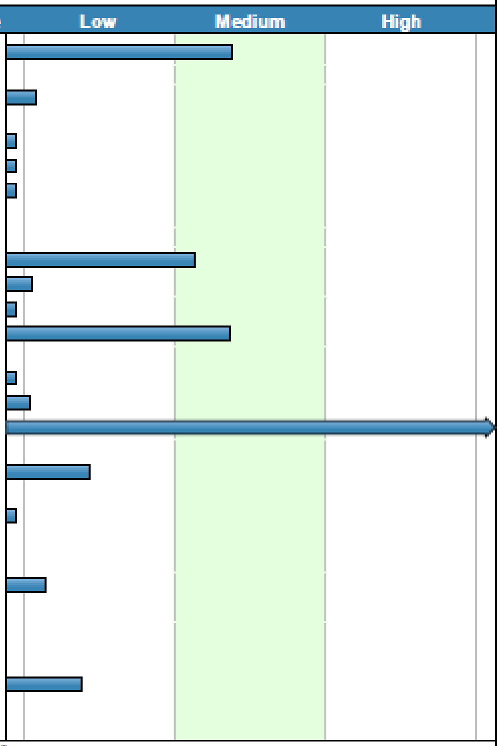

Figure 11. Deep pit soil test results from a ryegrass paddock in February 2015.

Sample Name: Baluka Maize | **Lab Number:** 1426186.3
Sample Type: SOIL General, Horticulture (S9)

Analysis		Level Found	Medium Range
pH	pH Units	6.6	5.8 - 6.5
Olsen Phosphorus	mg/L	5	25 - 50
Potassium	me/100g	0.09	0.50 - 1.00
Calcium	me/100g	10.1	6.0 - 12.0
Magnesium	me/100g	3.04	1.00 - 3.00
Sodium	me/100g	0.15	0.00 - 0.50
Potassium	%BS	0.6	3.0 - 6.0
Calcium	%BS	63	50 - 75
Magnesium	%BS	18.9	7.0 - 15.0
Sodium	%BS	0.9	1.0 - 2.0
CEC	me/100g	16	12 - 25
Total Base Saturation	%	83	60 - 85
Volume Weight	g/mL	1.10	0.60 - 1.00
Sulphate Sulphur	mg/kg	2	10 - 20
Available Nitrogen (15cm Depth)*	kg/ha	< 10	100 - 150
Anaerobically Mineralisable N*	µg/g	< 5	
Organic Matter*	%	0.9	7.0 - 17.0
Total Carbon*	%	0.5	
Total Nitrogen*	%	0.05	0.30 - 0.60
C/N Ratio*		10.0	
Anaerobically Mineralisable N/Total N Ratio*	%	< 0.5	3.0 - 5.0
Soil Sample Depth*	mm	0-1000	
MAF Units		K 2 Ca 14	Mg 75 Na 8

Figure 12. Deep pit soil test results from a maize crop on Wakanui silt loam in February 2015

In contrast to Figures 10. & 11. (Lismores), the Wakanui soil (Figure 12.) shows higher nutrient levels. This soil is very deep and highly compacted silt. There was no visible root activity in the zone that this sample was collected from. This soil is formed from windblown silt that was deposited during an inter-glacial period, and so may have given rise to naturally higher nutrient levels derived from limestone parent materials and/or estuarine sediments.

Given that the above soil testing information was indicating that there is likely to be large differences in deep soil nutrients between sites and soils, verification of the probe information was required as a means of “ground truthing” Hence the probe at this site. was excavated and removed from the kale in late October prior to spring cultivation operations some 4 weeks after the effluent drainage had ceased to register.

At this time another set of soil samples were then taken from three separate horizons down the profile (Figure 15a, 15b, & 15c.) within the column of soil visible to the probe, along with a normal representative whole paddock test across the entire paddock where the grazing of the kale had been completed. (Figure 14.)

Figure 13. View of sampling site during removal of the probe.

Sample Name: NP#1 G/F Kale **Lab Number:** 1496662.1
Sample Type: SOIL General, Horticulture (S9)

Analysis		Level Found	Medium Range
pH	pH Units	6.0	5.8 - 6.5
Olsen Phosphorus	mg/L	26	25 - 50
Potassium	me/100g	0.40	0.50 - 1.00
Calcium	me/100g	8.3	6.0 - 12.0
Magnesium	me/100g	0.69	1.00 - 3.00
Sodium	me/100g	0.16	0.00 - 0.50
Potassium	%BS	2.5	3.0 - 6.0
Calcium	%BS	54	50 - 75
Magnesium	%BS	4.4	7.0 - 15.0
Sodium	%BS	1.1	1.0 - 2.0
CEC	me/100g	16	12 - 25
Total Base Saturation	%	62	60 - 85
Volume Weight	g/mL	1.08	0.60 - 1.00
Sulphate Sulphur	mg/kg	17	10 - 20
Boron	mg/kg	1.0	1.0 - 2.0
Available Nitrogen (15cm Depth)*	kg/ha	82	100 - 150
Anaerobically Mineralisable N*	µg/g	51	
Organic Matter*	%	3.9	7.0 - 17.0
Total Carbon*	%	2.3	
Total Nitrogen*	%	0.25	0.30 - 0.60
C/N Ratio*		9.2	
Anaerobically Mineralisable N/Total N Ratio*	%	2.0	3.0 - 5.0
Iron	mg/kg	226	
Manganese	mg/kg	44	50 - 400
Zinc	mg/kg	3.1	2.0 - 10.0
Copper	mg/kg	2.4	1.0 - 5.0
Cobalt	mg/kg	0.6	2.0 - 4.0
Soil Sample Depth*	mm	0-300	
Soil Type*		Sedimentary	
MAF Units		K 9 Ca 11	Mg 17 Na 8

Figure 14. Soil test results from the whole paddock sample after grazing was completed.

Sample Name: Cult'n Layer 2-300 **Lab Number:** 1494358.1
Sample Type: SOIL General, Horticulture (S9)

Analysis		Level Found	Medium Range
pH	pH Units	6.2	5.8 - 6.5
Olsen Phosphorus	mg/L	28	25 - 50
Potassium	me/100g	0.54	0.50 - 1.00
Calcium	me/100g	11.0	6.0 - 12.0
Magnesium	me/100g	1.41	1.00 - 3.00
Sodium	me/100g	0.23	0.00 - 0.50
Potassium	%BS	3.0	3.0 - 6.0
Calcium	%BS	61	50 - 75
Magnesium	%BS	7.9	7.0 - 15.0
Sodium	%BS	1.3	1.0 - 2.0
CEC	me/100g	18	12 - 25
Total Base Saturation	%	74	60 - 85
Volume Weight	g/mL	0.96	0.60 - 1.00
Sulphate Sulphur	mg/kg	9	10 - 20
Chloride	mg/kg	32	
Available Nitrogen (15cm Depth)*	kg/ha	116	100 - 150
Anaerobically Mineralisable N*	µg/g	81	
Organic Matter*	%	6.1	7.0 - 17.0
Total Carbon*	%	3.5	
Total Nitrogen*	%	0.31	0.30 - 0.60
C/N Ratio*		11.5	
Anaerobically Mineralisable N/Total N Ratio*	%	2.6	3.0 - 5.0
Soil Sample Depth*	mm	0-300	
Soil Type*		Sedimentary	
MAF Units		K 11 Ca 13	Mg 30 Na 10

Figure 15a. Soil test results cultivated layer within bund under effluent after cessation of drainage.

Sample Name: Mid Probe 5-700 **Lab Number:** 1494358.2
Sample Type: SOIL General, Horticulture (S9)

Analysis		Level Found	Medium Range	Low	Medium	High
pH	pH Units	6.3	5.8 - 6.5			
Olsen Phosphorus	mg/L	9	25 - 50			
Potassium	me/100g	0.05	0.50 - 1.00			
Calcium	me/100g	2.3	6.0 - 12.0			
Magnesium	me/100g	0.13	1.00 - 3.00			
Sodium	me/100g	0.11	0.00 - 0.50			
Potassium	%BS	1.0	3.0 - 6.0			
Calcium	%BS	40	50 - 75			
Magnesium	%BS	2.2	7.0 - 15.0			
Sodium	%BS	1.9	1.0 - 2.0			
CEC	me/100g	6	12 - 25			
Total Base Saturation	%	45	60 - 85			
Volume Weight	g/mL	1.26	0.60 - 1.00			
Sulphate Sulphur	mg/kg	5	10 - 20			
Chloride	mg/kg	16				
Available Nitrogen (15cm Depth)*	kg/ha	13	100 - 150			
Anaerobically Mineralisable N*	µg/g	7				
Organic Matter*	%	1.4	7.0 - 17.0			
Total Carbon	%	0.8				
Total Nitrogen	%	0.05	0.30 - 0.60			
C/N Ratio*		15.1				
Anaerobically Mineralisable N/Total N Ratio*	%	1.3	3.0 - 5.0			
Soil Sample Depth*	mm	0-1000				
Soil Type*		Sedimentary				
MAF Units		K 1 Ca 4	Mg 4 Na 6			

Figure 15b. Soil test results mid probe after effluent drainage.

Sample Name: Below Probe 12-1400 **Lab Number:** 1494358.3
Sample Type: SOIL General, Horticulture (S9)

Analysis		Level Found	Medium Range	Low	Medium	High
pH	pH Units	5.8	5.8 - 6.5			
Olsen Phosphorus	mg/L	5	25 - 50			
Potassium	me/100g	0.03	0.50 - 1.00			
Calcium	me/100g	< 0.5	6.0 - 12.0			
Magnesium	me/100g	< 0.04	1.00 - 3.00			
Sodium	me/100g	< 0.05	0.00 - 0.50			
Potassium	%BS	1.2	3.0 - 6.0			
Calcium	%BS	18	50 - 75			
Magnesium	%BS	1.3	7.0 - 15.0			
Sodium	%BS	1.3	1.0 - 2.0			
CEC	me/100g	3	12 - 25			
Total Base Saturation	%	22	60 - 85			
Volume Weight	g/mL	1.47	0.60 - 1.00			
Sulphate Sulphur	mg/kg	3	10 - 20			
Chloride	mg/kg	< 10				
Available Nitrogen (15cm Depth)*	kg/ha	< 10	100 - 150			
Anaerobically Mineralisable N*	µg/g	< 5				
Organic Matter*	%	0.4	7.0 - 17.0			
Total Carbon	%	0.2				
Total Nitrogen	%	< 0.04	0.30 - 0.60			
C/N Ratio*		10.3				
Anaerobically Mineralisable N/Total N Ratio*	%	< 0.5	3.0 - 5.0			
Soil Sample Depth*	mm	1200-1800				
Soil Type*		Sedimentary				
MAF Units		K < 1 Ca < 1	Mg 1 Na 2			

Figure 15c. Soil test results below probe after cessation of effluent drainage.

Figure 16. View of sampling site below probe showing sandy soil texture.

Results from Figure 16. are shown in Figure 15c.

Conclusion

Laboratory analyses of soil samples from this site have clearly demonstrated that nutrients remaining after winter grazing of the second consecutive green feed crop (kale following beet); as well as the additional barn effluent applied; have been contained well within the root zone of the crop after drainage. Such nutrient is thus potentially available to be utilised by current and subsequent crops. Furthermore,ongoing deployment of objective actual measurement by Sentek probe and accurate soil testing is highly likely to affirm that appropriate nutrient management strategies can be employed to mitigate any actual, or perceived, risk of nutrient losses to ground water. This approach also has the added advantage of giving growers the confidence to work to increase the yield potential of the crops they grow, knowing that robust technology is available to measure the NUE and WUE of the cropping systems they choose to employ. This approach can also provide objective proof of good practice and environmental stewardship.