

Soil Pit Field Day in the Coomandook Area

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1 Introduction

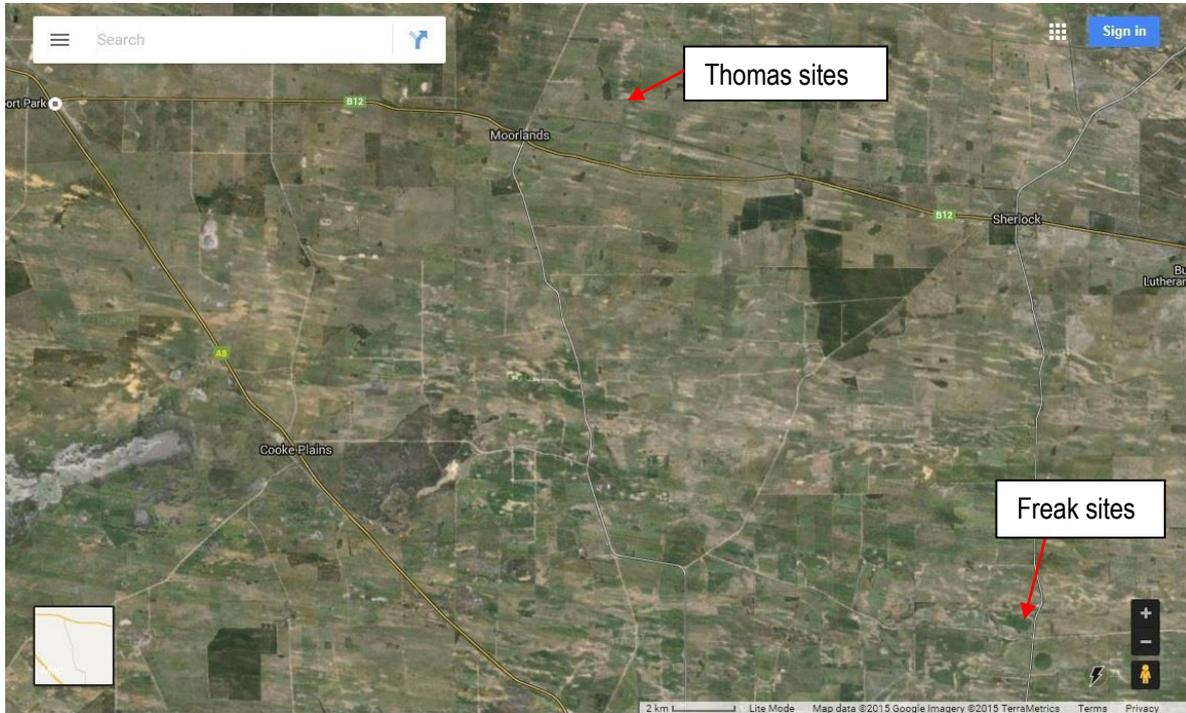
In discussions with the Coomandook Agricultural Bureau regarding opportunities to improve knowledge of constraints and barriers to primary production, the group determined the following as priorities:

- Undertake full soil profile classification and characterisation, assessment and analysis of chemical and physical properties and identification of chemical and physical constraints, limitations and barriers to primary production on two soil types on two farms (4 soil pits total)
- Identification of plant available moisture within each soil type
 - o Each soil type will have a soil capacitance probe and rain tipping bucket purchased and installed by Natural Resources SAMDB to enable determination of the plant available water and plant water use throughout the soil profile.
- Development of a report to identify the current positive primary production aspects of each soil, the constraints, limitations and barriers to crop growth with recommendations of actions and solutions to overcome these, and any future investigations that might be required to find solutions to overcome these.
- Delivery of a field day to convey the results and findings of the project to Coomandook Agricultural Bureau Members and guests
- Discuss with the Coomandook Agricultural Bureau Members their priorities for addressing the identified constraints, limitations and barriers and assist to develop a prioritised list of actions / trials / activities and investigations.

This report details the findings from the soil pits on each property. The field day was delivered on Friday 10th April 2015.

2 Maps

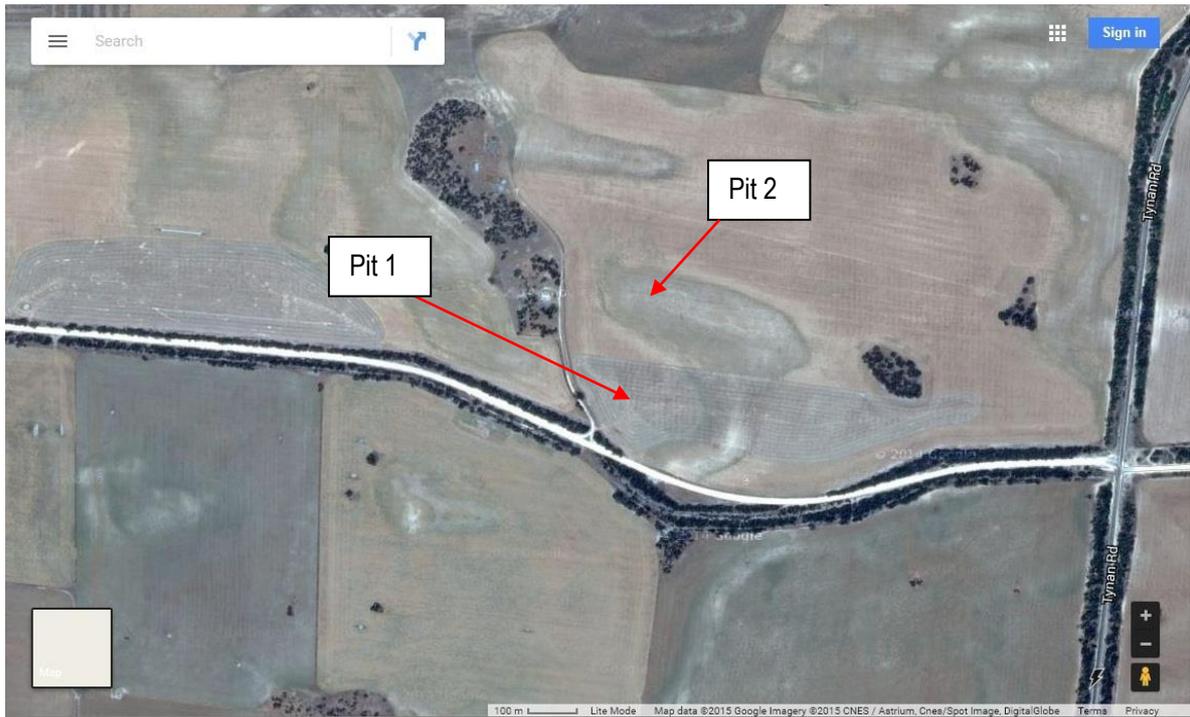
2.1 Area Map



2.2 Closer view of Thomas sites



2.3 Closer view of Freak sites



3 Useful Information

3.1 Critical Soil Nutrient Values (for wheat & similar crops)

			Soil Test Levels, Cereals				
			Deficient	Marginal	Adequate	High	Toxic
N	NITROGEN	%					
		mg/kg					
	Nitrate	mg/kg			20-40		
	Ammonium	mg/kg					
	Colwell						
P	PHOSPHORUS	mg/kg	<15		20-35		
P	DGT PHOS	units	<45	45-56	57-100	>100	
K	POTASSIUM	mg/kg			100-120		
		%					
S	SULPHUR	mg/kg			6-15		
		%					
Na	SODIUM	%			<6		
Ca	CALCIUM	mg/kg			600		
Mg	MAGNESIUM	mg/kg			100		
Cl	CHLORIDE	mg/kg			<120		
Cu	COPPER	mg/kg			1		
Zn	ZINC	mg/kg			1.2-2.0		
Mn	MANGANESE	mg/kg			10-50		
Fe	IRON	mg/kg					
B	BORON	mg/kg			0.5-5		>5

** Note that these levels are given as a guide only. Actual nutrient levels required will vary depending on the soil type, environmental conditions and the crop grown.

3.2 Soil Water Holding Capacity by Texture

Texture group	Water holding capacity (mm water/metre soil)	
	Readily available (8-60 kPa)	Total available (8-1500 kPa)
Medium to coarse sand	30-50	40-80
Fine sand	40-60	60-100
Loamy sand	50-70	80-120
Sandy loam	40-70	100-140
Light sandy clay loam	60-90	110-170
Loam	80-100	140-200
Sandy clay loam	70-90	130-180
Clay loam	60-90	150-220
Clay	50-70	120-220

Adapted from Wetherby (1992) and Dent and Young (1981), by Maschmedt (2000).

Note that compaction, chemical toxicities, salinity and rock will reduce potential available water.

Readily available water (RAW) is that water which plants can access with very little effort, from water suction of 8-60 kPa). Total available water (TAW) is water theoretically available to plants from 8 kPa of suction pressure (Field Capacity) down to 1500 kPa of suction pressure (Wilting Point). Different plants have difference tolerances within this spectrum as well. The ability of the plant to extract water from the soil becomes progressively more difficult as the water suction (matric potential) increases.

Classification criteria for available water holding capacity (AWHC).

The root-zone of wheat is used as the benchmark for this table.

AWHC category	Rootzone AWHC
High	> 100 mm
Moderate	70-100 mm
Moderately Low	40-70 mm
Low	20-40 mm
Very Low	< 20 mm

Water storage capacity is considered non limiting if the storage in the root-zone is > 100mm. Soils with less than 20 mm storage capacity in the root-zone are generally considered non arable as they cannot hold enough water to allow crops to mature.

Table adapted from Maschmedt, 2000.

3.3 Soil Water Holding Capacity Concepts

Programs such as Yield Prophet and others use soil characteristics such as water holding capacity and nutrition to predict potential yield of crops under various conditions. For the program to be most accurate, good measurements of the soil characteristics are vital.

Some measurements which are useful to understand are:

Gravimetric water content

The weight of water in the soil, measured by weighing wet soil, drying in an oven (40 °C), and re-weighing. Wet soil wt – dry soil weight = water weight. This is converted to a % figure for gravimetric water content.

Volumetric metric water content

Gravimetric water content (%) multiplied by soil bulk density.

Field Capacity/Drained Upper Limit

This is the amount of water measured in the soil after it has been saturated and then allowed to drain for (usually) 24-48 hours. Sandy soils drain very fast and need to be measured soon after saturation. Some clay soils do not drain and may be difficult to measure. Saturation may be achieved by heavy rain, or by wetting up the soil using a soaker hose and a water tank. Evaporation should be minimised to measure the true amount of water in the upper soil. Published data on FC and soil types may be used when necessary. **FC/DUL is expressed as Volumetric Water %.**

Crop Lower Limit

This is the amount of water left after a crop has extracted all the water possible. Different crops vary in the amount of water they can extract, so wheat is commonly used as a standard. This can be measured in the field by erecting a rain-out shelter over a growing crop at flowering, and allowing the crop to dry the soil out as much as possible, then measuring the soil water content. The soil water will change throughout the profile depending on the ability of the crop to extract water, and the extent of root growth. **CLL is expressed as Volumetric Water %.**

Bulk Density

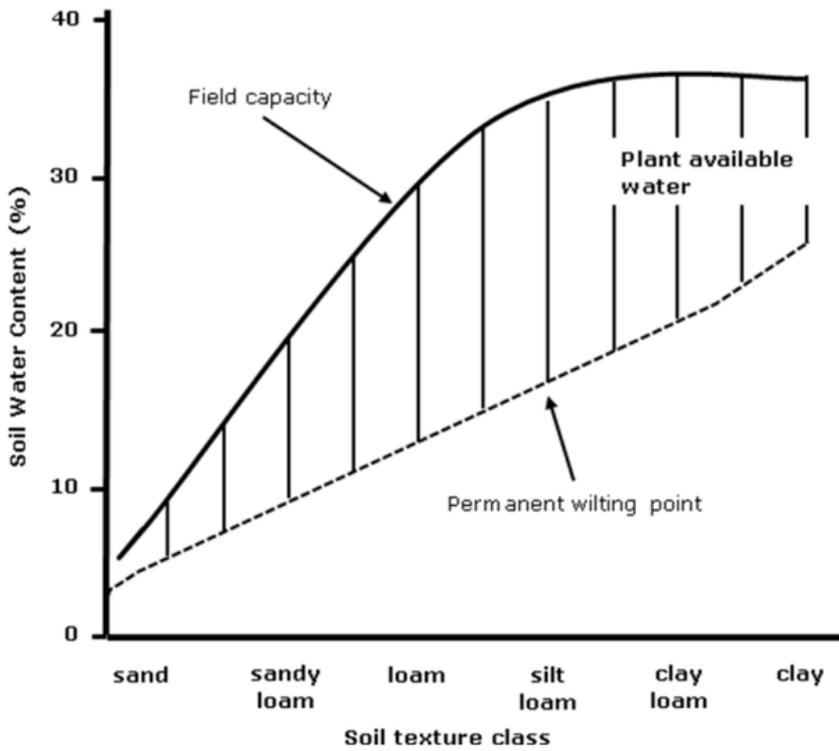
This is a measurement of the weight of soil in a given volume. A sample of soil is taken using a container with an accurate specific volume, dried and weighed. This gives the weight of soil in grams per cubic cm, which can be converted to t/m³. Presence of rock can make measuring bulk density difficult.

Plant Available Water Capacity

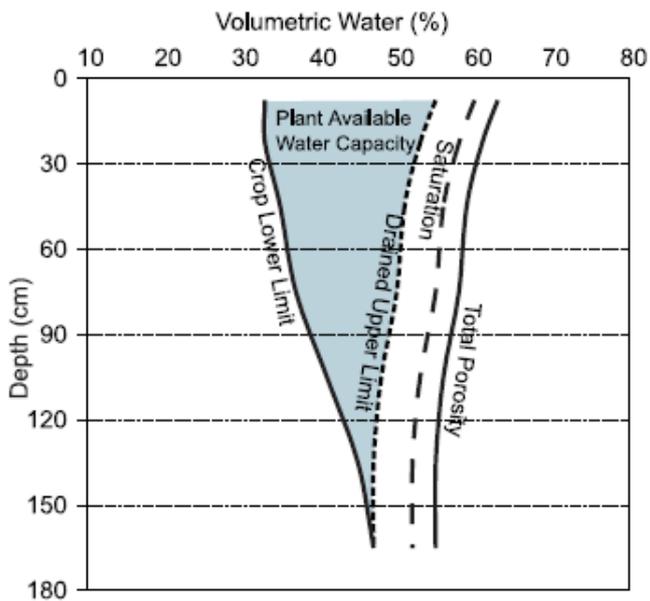
PAWC is defined as the amount of water a given crop can access at a given depth of soil. It is the DUL – CLL , multiplied by the depth of the soil in the profile. The PAWC alters down the profile with root density and soil type, and may need to be calculated in a series of layers that are added together to get the total.

Both CLL and DUL are measured gravimetrically, by taking a soil sample, weighing it, then drying it and weighing again to calculate the weight of water that was contained in the sample. This is then converted to mm water per m depth of soil using the Bulk Density measurement. Published data on crops and soil types may be used when necessary.

Soil water holding capacity varies with texture. Sandy soils hold little water, but give it up easily. Clay soils hold a lot of water, but hold it strongly.



Below is an example of a water storage profile from the APSIM manual at <https://www.apsim.info/Portals/0/APSoil/SoilMatters/pdf/Mod4.pdf>



4 Andrew Thomas Pits

4.1 Soil Pit 1 – mid-slope

4.1.1 Characterisation

This soil was characterized as an Endohypersodic, Marly Hypercalcic Calcarosol; thick, slightly gravelly, sandy/loamy, very deep [?].

This description indicates that the soil has sodicity in the lower B horizon, combined with a mixture of soft lime and clay (marl). There is a large amount of carbonate throughout the B horizon and the A horizon also contains some carbonates as fine earth and rocky fragments. The A horizon is thick (30-40 cm deep), with some small rocks and carbonate (slightly gravelly), and the A horizon has a texture of a sandy loam to loam, while the B horizon is a loam. The soil contains some calcrete, but was able to be excavated to 1.5 m. It is not known how much deeper the soil may go before reaching rock.

	0-10	Brown loam, weak platy gradual to:
	10-30	Lighter brown loam, weak platy structure, gradual to:
	30-50	Calcareous rubble at about 30-40 cm (variable).
	50-70	Fine clayey sand with high level of powdery carbonates.
	70-90	There are high levels of sodium, salinity and boron at depth, but well below the root zone.
	90+	

The topsoil and subsoil show signs of compression – note the horizontal tendency of the soil structure. Root growth is good to 30 cm, and is then restricted by hard calcrete nodules and rocks. Some roots have been able to penetrate deeper (50-60 cm) through cracks in rocks.

Depth	Texture	Rock %	Sand %	Silt %	Clay %
0-10	Loam		75	0	25
10-30	Loam		75	0	25
30-50	Sandy loam	80-100	80	0	20
50-70	Fine clayey sand		93	0	7
70+	Fine clayey sand		93	0	7

4.1.2 Chemical Analysis Pit 1

Please see Appendix 1 for table of full chemical analysis results for A Thomas soils.

pH of the surface soil is neutral to mildly alkaline, and should be fine for crops that tolerate carbonates.

EC 1:5 is low in the topsoil (<2.0 ECe) (when multiplied by the soil conversion factor), and salinity should not be a problem there. Salinity rises in the 50-70 cm and 70-90 cm depths to 5 and 6 ECe, and could be a problem for crop plants. Note that root growth currently stops in this area.

Boron levels are also high/toxic in this 60 cm + zone, showing that this is the area that salts are leached to in this soil.

Potassium levels are adequate in the topsoil (marginal from 30-50 cm, but this should not affect the crop under normal conditions).

The soil analysis shows low levels of Copper and Manganese in the topsoil – these should be increased or foliar sprays used for field crops. Zinc is adequate in the topsoil, but low in the 10-30 zone. Iron levels should be adequate, but check in crop for signs of deficiency for all trace elements.

Nitrate levels when the soil samples were taken were good – nitrate is very mobile and levels can change quickly with moisture and weather patterns.

P levels were 43 Colwell, with a PBI of 43 (low-moderate). This indicated good levels of P available to plants, which is backed up by the DGT P results of 268 – DGT P levels over 100 indicate sufficient P for field crops.

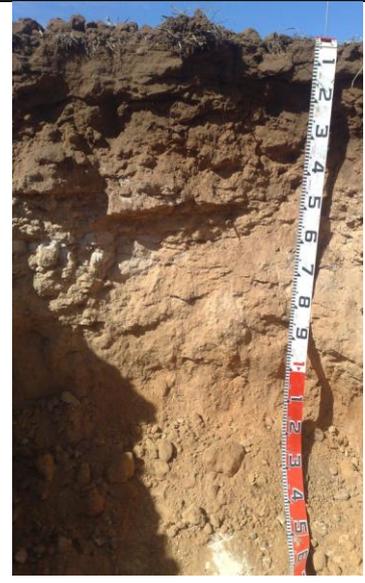
Sulphur levels in the 0-30 cm layer are marginal, and the soil may benefit from some sulphur fertilizer.

Cation Exchange Capacity (CEC, a measure of nutrient holding capacity) is good for this soil type, and the soil should not have problems retaining nutrients or giving them up to plants in the 0-30 cm depths. Below that, high carbonates will affect nutrient availability.

Organic Carbon levels are reasonable for this soil type and rainfall area, and continue in the 10-30 cm layer.

4.1.3 Estimated Water Holding Capacity in the Root Zone

An estimate of WHC can be made using the soil layer textures (taking into account rocks and gravel) in the soil in which roots are able to grow. Please note that this is an estimation only. Actual Water Use Efficiency will vary depending on the season.

	<p>Texture</p> <p>0-35 loam</p> <p>35-60 loam and rubble</p>	<p>Available Water</p> <p>35 cm * 180mm/m = 63mm</p> <p>25 cm but rubbly, limiting water availability</p> <p>25 * 100 = 25 mm</p> <p>Very few roots below 60 cm</p> <p>Total est. water storage available in root zone – 87mm</p>
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4.1.4 Positive Primary Production Aspects

The loamy soil has sufficient depth that rockiness should not be a problem for machinery, and the only constraints to root growth in the upper soil occur where there is solid calcrete rubble. Roots grow through cracks in the rubble down to ~ 60 cm. At this depth chemical constraints from boron, salinity and carbonates reduce root growth.

There is a fairly good water holding capacity in the soil within the root zone, and the soil appears to take in water readily (no problems with water repellence).

P levels are currently good and show good availability.

The soil has good nutrient holding capacity and would not be too prone to leaching or erosion when managed well.

4.1.5 Soil aspects for Improvement

Improving this type of soil would focus on the top 30 cm, as any work below this would not be economic due to the thick calcrete rubble and chemical constraints.



The soil structure appears somewhat platy, indicating compression in the past. However, this does not appear to have caused any problems for root growth. Best methods to encourage improved structure are to minimise compacting traffic as much as possible, and to retain organic matter.

Improving this soil would focus on raising the Sulphur levels, which are currently marginal, and improving trace elements levels for Copper and Manganese. Bearing in mind that the pH is slightly alkaline (alkaline soils lock up Cu, Mn and Zn), this may be difficult to achieve. Foliar applications in crop to test whether the crop will respond are recommended. Test strips in the paddocks may be useful to see whether trace elements in the soil are an economic option.

**Note that micro-elements such as cobalt and molybdenum were not tested in this project.

4.2 Soil Pit 2 – top of rise

4.2.1 Characterisation

This soil was characterized as an Epibasic Marly Hypercalcic Calcarosol; thick, non-gravelly, sandy/loamy, very deep [?].

This description indicates that the soil is alkaline but not sodic in the lower B horizon, combined with a mixture of soft lime and sandy clay (marl). There is a large amount of carbonate throughout the B horizon but the A horizon is loamy sand, with some organic matter in the top 10 cm, and bleached sand below this. The B horizon is a light sandy clay. The soil contains some calcrete, but was able to be excavated to 1.5 m. It is not known how much deeper the soil may go before reaching rock.

	0-10	Brown sandy loam, single grained structure, gradual to:
	10-30	Bleached sand, single grained, clear boundary to:
	30-50	Yellow light sandy clay, clear to:
	50-80 +	Calcrete rubble over calcareous light sandy clay loam.

The surface may have some water repellence. Root growth is high in the surface 0-10 cm, but reduces quickly in the 10-30 cm sand layer, with very few roots below this.

4.2.2 Chemical Analysis Pit 2

Please see Appendix 1 for table of full chemical analysis results for A Thomas soils.

The soil has neutral pH in the surface, becoming more alkaline with depth. Alkalinity may affect some nutrient availability below 50 cm.

E_{Ce} (calculated) indicates that salinity is not a problem at this site. Boron levels are also low until the 90-120 cm layer.

Potassium levels are sufficient in the soil.

Copper and manganese are deficient, similar to pit 1.

Nitrate levels are low, probably due to the sandy soil having little capacity to hold nutrition. This is supported by the low CEC in the topsoil, and low organic carbon.

Colwell P is adequate and PBI is low – leaching of P might be possible at this site under heavy rain or wet conditions. DGT P shows high levels of available P.

Sulphur levels are low at this site (sulphur is prone to leaching on sandy soils).

4.2.3 Estimated Water Holding Capacity in the Root Zone

An estimate of WHC can be made using the soil layer textures (taking into account rocks and gravel) in the soil in which roots are able to grow.

	Texture	Available Water
	0-10 loamy sand	10 cm * 120mm/m = 12 mm
	10-30 sand	20 * 60 = 12
	Very few roots below this bleached sand layer.	<u>Total in root zone = 24 mm</u>
	30-50 – light sandy clay and rubble	If root zone were extended below bleached layer: 10 cm * 150mm/m = 15 mm
50-70 – light sandy clay	20 cm * 150 = 30 mm Extra 45 mm of stored water *might* be able to be accessed.	

Depth	Texture	Rock %	Sand %	Silt %	Clay %
0-10	Loamy sand		95	0	5
10-30	Sand		100	0	0
30-50	Sandy loam	50	85	0	15
50-70	Fine clayey sand		93	0	7
70+	Fine clayey sand		93	0	7

4.2.4 Positive Primary Production Aspects

Positive aspects of this soil are easy working, and gives up water and nutrients easily to the crop.

4.2.5 Soil aspects for Improvement

The limitations are caused by the light soil texture with low nutrient holding capacity in the topsoil, with limited capacity to modify the soil due to calcrete rubble close to the surface.

Water repellence may be a problem in some years.

Soil chemistry indicates low CEC in the surface, and low levels of Copper and Manganese.

This soil may benefit from top-up fertilizer applications in good years, or slower release forms of fertilizer to ensure that the crop has nutrition throughout the season. Building CEC could be done with organic matter.

Claying may be too expensive unless a good source is located close by, and care would have to be taken to incorporate to 30 cm to ameliorate the bleached sand, but without breaking machinery or causing problems with rocky rubble underneath.

Deep tillage or delving could be risky given the hard carbonate rubble at 40-50 cm, and the varying depth of rubble through the rise. Deep placement of organic matter or nutrition using a slotter or a similar setup would

help to encourage root growth through the bleached sand to take advantage of moisture deeper in the soil profile, and would probably cope better with rubble than a larger machine.

Addressing trace element deficiencies is likely to be most profitable in the short term.

**Note that micro-elements such as cobalt and molybdenum were not tested in this project.

5 Tim Freak Pits

5.1 Soil Pit 1 – Grey Clay Flat

5.1.1 Characterisation

This soil was characterized as an Endohypersodic Marly Lithocalcic Calcarosol; thick, slightly gravelly, loamy/loamy, very deep [?].

This description indicates that the soil has a highly sodic horizon below 50 cm (at 50-80 cm), a combination of clay and fine calcareous earth in the B horizon (marl), a rocky calcrete layer (50 cm) and is a soil dominated by carbonates. The A horizon is thick (> 30 cm), slightly gravelly, has loam texture in the A and B horizons, and has a depth of more than 1.5 m (limit of pit).

	<p>0-40</p> <p>40-50</p> <p>50-70</p> <p>70+</p>	<p>Dark Grey loam with weak cloddy structure to 30 cm, clear to:</p> <p>Increasing soft carbonate and calcrete in loam, to:</p> <p>Calcrete plates with cracks, some fine soft loam, continuing to:</p> <p>A mixture of soft carbonates, calcrete rubble and fine clayey loam</p>
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This soil grows high biomass crops early in the season, but is prone to haying off.

The pit shows good depth of roots, as they are throughout the profile to 50 cm. At 50 cm, hard platy sheet calcrete is restricting growth of roots. Some are able to grow through cracks, and reach to 50-70 cm, however carbonates and salt are also a problem below 50 cm.

The platy calcrete may be a temporary barrier to drainage in times of heavy rain.

5.1.2 Chemical Analysis Pit 1

Please see Appendix 2 for table of full chemical analysis results for T Freak soils.

The pH of the soil here is alkaline at the surface, grading to strongly alkaline at depth. Nutrients such as phosphorus, copper, zinc and manganese may be locked up at this pH.

Est ECe shows mild salinity in the 10-30 cm layer, which could affect sensitive crops such as beans. Salinity rises in the 30-50 and 50-80cm layers, which would be affecting all crops and restricting root growth and water availability. Boron levels also rise in the 50-80 cm layer and below.

Potassium levels are good in the surface 0-10 cm, but are low in the 10-30 cm layer. This may restrict potassium to the plant if the surface soil is dry.

Copper, zinc and manganese levels are all low. The alkaline soil is likely to tie up soil applied trace elements. Foliar applications may be more effective.

Iron levels also appear low – a test strip of iron application to the crop would show whether the crop will respond to iron.

Organic carbon levels are reasonable, and CEC is high. The soil is able to hold nutrients, but may not give them up as easily.

Colwell P levels appear sufficient for the soil texture (loam), but the PBI is very high (143) due to the high carbonate levels. DGT P levels show 53, which is marginal for phosphorus. Higher P applications may be needed for a good cereal or oilseed crop.

Sulphur levels are low, and are probably limiting crop production.

Sodium levels are high in the subsoil due to salinity and possibly some sodicity.

5.1.3 Estimated Water Holding Capacity in the Root Zone

An estimate of WHC can be made using the soil layer textures (taking into account rocks and gravel) in the soil in which roots are able to grow.

	<p>Texture</p> <p>0-40 cm – loam</p> <p>40 – 140 cm – loam with varying amounts of calcrete rubble, also chemical constraints.</p> <p>Roots to 60 cm.</p>	<p>Available Water</p> <p>40 cm * 180mm/m = 72 mm</p> <p>20 cm * 100 = 20 mm</p> <p>Total est. water capacity in root zone (taking rubble & chemistry into account) = 92 mm</p>
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Depth	Texture	Rock %	Sand %	Silt %	Clay %
0-40	Loam		75	0	25
40-50	Loam	50%	75	0	25
50-70	Loam	80-100	75	0	25
70-140+	Fine clayey loam	25%	70	0	30

5.1.4 Positive Primary Production Aspects

This soil is flat, usually easily worked (except after heavy rain), and has good water storage capacity. It also has high nutrient storage capacity. The texture allows it to take in water easily and store it to give up to plants.

Tim Freak notes that this soil grows high biomass crops early in the season, but is prone to haying off.

5.1.5 Soil aspects for Improvement

This soil is constrained by the rocky calcrete layer, which restricts some root growth and may lead to temporary water logging after heavy rain. It is also constrained by the high levels of carbonates in the soil, which affect nutrient availability, and by elevated salinity and boron levels from 50 cm downwards.

The constraints which are most likely to be addressed economically are the low availability levels of some nutrients. Building up P levels to the point where more P is available to crops will help, as will including a source of sulphur in the fertilizer. Addressing trace element deficiency would also be beneficial. This is probably most economically done via foliar sprays, as high carbonate levels will tend to lock up trace elements in the soil. Some good effects may be obtained using liquid injection of trace elements, or by banding below the seed.

Managing crop canopy early in the season may help to reduce the rate of water use and allow the crop to finish better. Using slow-release fertilizer, or timing applications so that early growth is reduced but finishing has adequate nutrition may be another option.

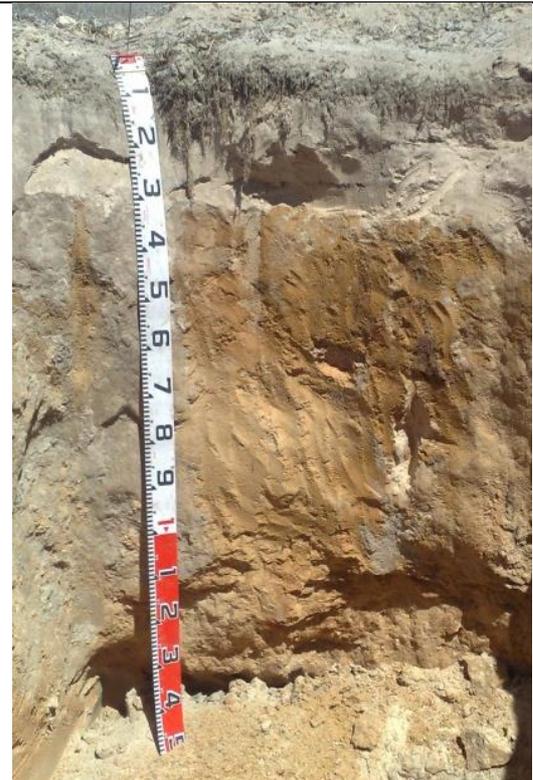


5.2 Soil Pit 2 – Sand Dune

5.2.1 Characterisation

This soil is described as a Bleached Hypercalcic Yellow Kandosol; medium, non-gravelly, sandy/loamy, very deep [?]. This pit is located ~ 70 m from pit 1.

It has a loamy sand topsoil (0-10 cm) over a bleached sandy A2 horizon. Below this is a light clayey sand, which gradually becomes calcareous and more sandy from 70 cm to 140 cm +. The contrast in texture between the A and B horizons is not large, and the structure of the B horizon is massive (ie, no organization into crumbs, clods, plates or peds).

	0-10	Grey loamy sand, single grained structure, gradual to:
	10-30	Bleached sand, single grained, clear to:
	30-70	Yellow light clayey sand, massive/single grained structure, gradual to:
	70-140+	Yellow light clayey sand as above containing increasing amounts of soft fine carbonate and some carbonate rubble.

Roots are concentrated in the 0-10 cm layer which contains some organic matter and nutrition, and are reluctant to go in to the 10-30 cm leached sand.

Carbonate is visible from 70 cm onwards. There is some rubble, but mostly fine carbonate powder.

5.2.2 Chemical Analysis Pit 2

Please see Appendix 2 for table of full chemical analysis results for T Freak soils.

The pH in the sand dune is neutral in the surface, changing to mildly alkaline with depth. Most alkalinity occurs when the soil contains carbonate at 60-130 cm (pH 8.24).

ECe (est) shows no salinity problems through the profile, probably due to being higher in the landscape with very good drainage. Boron levels are also low.

Potassium levels are low in the 0-30 cm and would be restricting crop growth.

Trace elements (Cu, Zn, Mn and Fe) are all low. The low CEC of the soil (only 3.5 in the surface) means that it is difficult to retain nutrition in the sand. To build up any nutrition levels in the surface soil will require increasing the CEC to above 6, using either clay, organic matter or a combination of both.

Colwell P value is only 13, which would generally be thought low even for a sandy soil. However, PBI is only 10.5 (very low), and DGT P shows as highly available at 202. It may be possible to reduce P applications and still have sufficient P for the crop.

5.2.3 Estimated Water Holding Capacity in the Root Zone

An estimate of WHC can be made using the soil layer textures (taking into account rocks and gravel) in the soil in which roots are able to grow.

	Texture	Available Water
	0-10 – loamy sand	10 cm * 100mm/m = 10 mm
	10-30 – sand, very few roots.	20 cm * 60 mm/m, 50% effective = 6 mm
	No roots below 30 cm.	<u>Total water in root zone = 16 mm</u>
30-70 cm – clayey sand	Water stored in clayey sand to 70 cm: 40cm * 150 mm = 60 mm	Potential water available if roots can get past bleached layer and use all water from 0-70 = 92 mm

Depth	Texture	Rock %	Sand %	Silt %	Clay %
0-10	Loamy sand		96	0	4
10-30	sand		99	0	1
30-70	Clayey sand	5	90	0	10
70-140+	Clayey sand		90	0	10

5.2.4 Positive Primary Production Aspects

The soil can give up water and nutrition easily, and does not lock it up. It is easily worked.

5.2.5 Soil aspects for Improvement

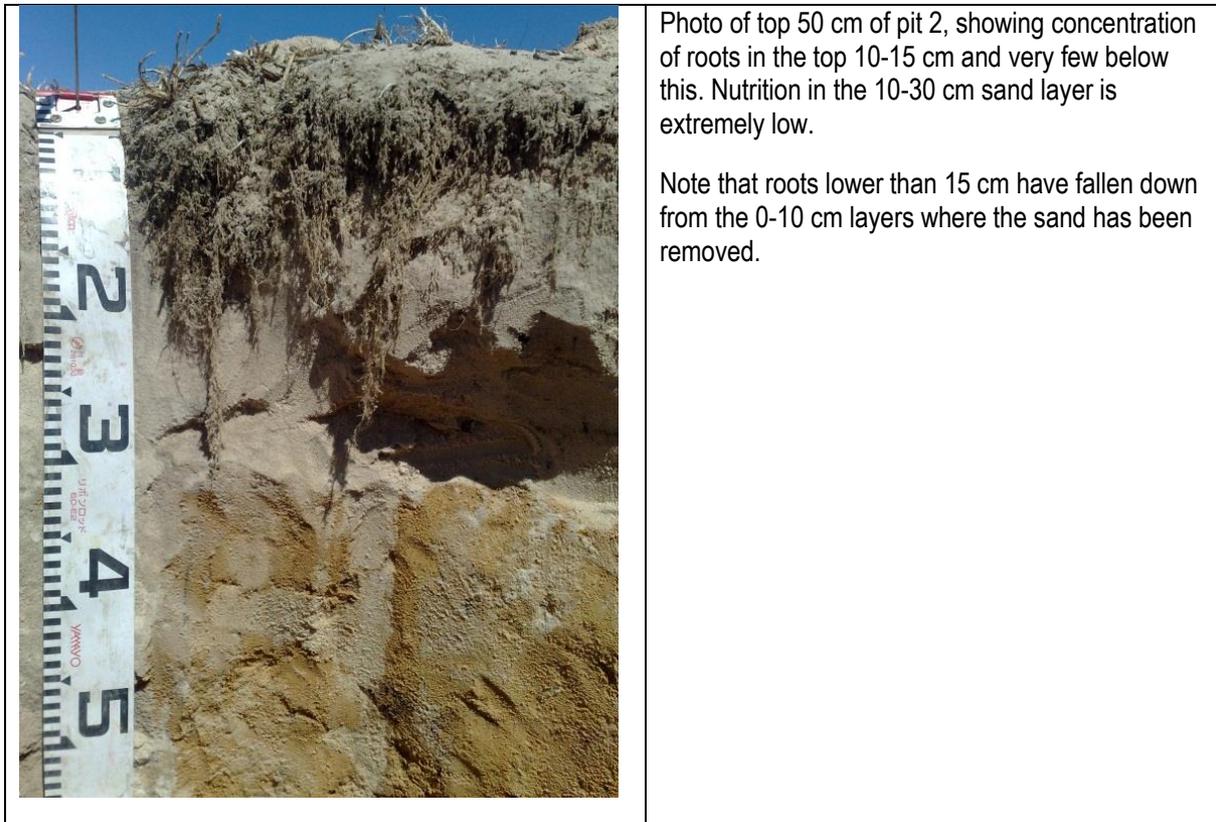
The sand may be water repellent to some degree.

The shallow root depth and low capacity of the soil to retain nutrients is limiting crop growth and yield.

Chemistry shows low CEC in the 0-10 and 10-30 cm layers, but the light sandy clay has higher CEC and could potentially be delved up to improve the upper layers. With low carbonate until deeper in the soil profile, this is an area which would respond well to delving. It would be worth investigating how large an area is like this and whether it would be worthwhile to get a delver in.

Alternatively, using compost or slow-release fertilizer on this area, or spading in organic matter, could also increase nutrition and get roots growing deeper into the soil. Placing nutrition at depth to improve root depth and water use efficiency is very important for this soil type.

Using slow-release or organic-based forms of P and K could also help with leaching problems.



6 Recommendations for Follow-up Action

A meeting with the Coomandook Ag Bureau and NRM representatives will be held on the 25th June to discuss further actions. Notes from that meeting will be added to the report.

6.1 Potential trials

- At Andrew Thomas' sites, improved nutrition with Sulphur and trace elements is likely to improve the soil. A trial comparing granular vs foliar trace elements may be helpful to determine the best source.
- At Tim Freak's, the grey clay site would benefit from improve P and S nutrition – some test strips could be useful. The trace element nutrition could also be addressed with test strips. However, managing early growth so that the site does not hay off is likely to still be challenging.
- At Tim's on the dune, trialing delving would be very interesting and likely to have excellent results, provided that the area is big enough to warrant the investment. Adding organic matter to the soil as well is likely to be beneficial. Slotting organic matter is another option.

7 Appendix 1 – Soil Chemistry Andrew Thomas

Sample Name	PHWater	PHCaCl	EC 1:5	ECe (est)	Boron	K	Ca	Mg	Na	Cu	Zn	Mn	Fe
			dS/m		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
A THOM 1 (0-10)	7.54	6.92	0.11	1.87	1.48	603.7	1919.9	210.4	42.7	0.36	1.87	9.1	8.7
A THOM 1 (10-30)	8.55	7.88	0.11	1.87	2.21	248.1	5415	302.2	50.6	0.38	0.07	1.18	3.1
A THOM 1 (30-50)	8.94	8.21	0.14	1.33	3.79	100.8	5378	634.3	143.7	0.62	0.1	1.58	2.9
A THOM 1 (50-90)	9.9	8.7	0.53	5.035	10.91	284.4	4432.2	744.6	960.5	0.29	0.09	0.32	1.1
A THOM 1 (90-150)	9.88	8.63	0.69	6.555	9.12	367.5	4109.8	744.5	1260.5	0.17	0.13	0.41	2.3
A THOM 2 (0-10)	7.48	6.79	0.05	0.85	0.65	140.3	904.3	153.6	14.2	0.18	2.34	3.69	14
A THOM 2 (10-30)	8.07	7.22	0.05	0.85	0.35	126.6	497.3	106.4	9.4	0.1	0.06	0.3	3
A THOM 2 (30-50)	8.84	8.05	0.1	0.95	1.66	393.3	4497.1	545.2	30.7	0.1	0.06	0.3	2.6
A THOM 2 (50-70)	9.15	8.39	0.11	1.045	2.45	223.8	4969.8	823.5	60.6	0.39	0.06	0.3	1
A THOM 2 (70-90)	9.24	8.41	0.11	1.045	1.84	268.6	4418.9	949.3	79.1	0.16	0.15	0.3	1.1
A THOM 2 (90-120)	9.6	8.51	0.14	1.33	4.18	367.6	4010.2	928.6	200.8	0.08	0.06	0.3	1
	Nitrate	Ammonium	Colwell K	Organic	Colwell P	PBI	DGT	KCL	Exch	Exch AI	CEC	ESP	
	NO3	NH3	mg/kg	Carbon	mg/kg		ug/L	Sulfur	Acid	g			
A THOM 1 (0-10)	27.5	3.3	566	1.24	43	36.6	268	7.4	0.01	0.01	13.1	1.4	
A THOM 1 (10-30)	10.6	2.8	221	1.17	5	115.5		9.6	0.01	0.01	30.4	0.7	
A THOM 1 (30-50)	6.3	1.9	57	0.74	5	252.8		11.3	0.01	0.01	33.1	1.9	
A THOM 1 (50-90)	3.4	1	259	0.31	5	183.8		18.3	0.01	0.01	33.3	12.6	
A THOM 1 (90-150)	2.2	1	332	0.1	5	338.8		65.3	0.01	0.01	33.2	16.5	
A THOM 2 (0-10)	4.4	3.5	163	0.74	26	13.8	289	9	0.01	0.01	6.2	1.0	
A THOM 2 (10-30)	2	1	144	0.13	13	14.8		5.6	0.05	0.01	3.7	1.1	
A THOM 2 (30-50)	2.7	1.1	388	0.17	5	70.2		4.7	0.01	0.01	28.2	0.5	
A THOM 2 (50-70)	1.3	1.4	229	0.51	5	245.7		6.8	0.01	0.01	32.5	0.8	
A THOM 2 (70-90)	1	1	262	0.21	5	153.8		8.4	0.01	0.01	31.0	1.1	
A THOM 2 (90-120)	1	1	340	0.11	5	314.5		1	0.01	0.01	29.6	2.9	

8 Appendix 2 – Soil Chemistry Tim Freak

Sample Name	PHWater	PHCaCl	EC 1:5 dS/m	ECe (est)	Boron mg/kg	K mg/kg	Ca mg/kg	Mg mg/kg	Na mg/kg	Cu mg/kg	Zn mg/kg	Mn mg/kg	Fe mg/kg
T FRE 1 (0-10)	8.58	7.94	0.16	1.52	3.79	465.2	6582.2	975.3	218.2	0.11	0.47	2.33	2.1
T FRE 1 (10-30)	9.15	8.31	0.27	2.565	3.98	64.1	5729.7	2013.2	708.7	0.13	0.06	0.3	1
T FRE 1 (30-50)	9.4	8.43	0.5	4.75	8.69	133.2	4826.4	2303.5	1355	0.46	0.06	0.3	1
T FRE 1 (50-80)	10.01	8.84	0.74	7.03	11.08	840.6	3674.9	1253.8	2257.3	0.12	0.06	0.3	1
T FRE 1 (80-130)	10.07	8.85	0.7	6.65	10.08	625.7	4022	857.5	1577.1	0.19	0.25	1.23	6
T FRE 2 (0-12)	7.5	7.07	0.06	1.02	0.35	44.6	524.2	84.3	17.3	0.11	0.1	0.86	2.2
T FRE 2 (12-30)	8.97	7.78	0.04	0.68	0.17	37.4	420.4	57.6	9	0.08	0.06	0.3	1.3
T FRE 2 (30-60)	8.47	7.65	0.08	0.76	0.46	267.2	1737	366.3	16.9	0.08	0.11	0.3	5.6
T FRE 2 (60-130)	9.05	8.24	0.08	0.76	0.54	119.5	4764.2	406.2	27.8	0.1	0.07	0.3	1.4
Sample Name	Nitrate NO3 mg/kg	Ammonium NH3 mg/kg	Colwell K mg/kg	Organic Carbon %	Colwell P mg/kg	PBI	DGT ug/L	KCL Sulfur mg/kg	Exch Acid c.mol/kg	Exch Al c.mol/kg	CEC (meq)	ESP	
T FRE 1 (0-10)	22.6	4.4	477	2.41	27	143.4	53	8.6	0.08	0.01	43.2	2.2	
T FRE 1 (10-30)	8.9	1.3	55	1.07	5	266.4		4.1	0.01	0.01	48.7	6.3	
T FRE 1 (30-50)	6.2	1.8	130	0.84	14	327.2		10.7	0.01	0.01	49.6	11.9	
T FRE 1 (50-80)	7.4	1	770	0.32	5	144.7		1	0.01	0.01	40.8	24.1	
T FRE 1 (80-130)	12.2	1	592	0.29	5	201.5		2	0.01	0.01	35.7	19.2	
T FRE 2 (0-12)	5.5	3	67	0.42	13	10.5	202	6.8	0.01	0.01	3.5	2.1	
T FRE 2 (12-30)	1.8	1	46	0.07	5	6.2		5.4	0.01	0.01	2.7	1.4	
T FRE 2 (30-60)	2.2	1	256	0.13	7	32.4		6	0.01	0.01	12.5	0.6	
T FRE 2 (60-130)	2.6	1.1	125	0.16	5	76.1		6.3	0.01	0.01	27.6	0.4	