Soils, Carbon & Productivity - Mt Charles & Keith

9am - 10.30am Mount Charles
11am - 1.30pm Keith Institute
Friday 29th October 2021

REGISTRATIONS for catering;
tstrugnell@coorong.sa.gov.au or
text on 0427 750 050
Register by Monday 25th October

9am Cnr Heron & Browns Road MT CHARLES

- Three soil pits across the landscape identifying limitations to plant growth
- On farm telemetry equipment for weather, ground water, soil moisture & salinity

11.00am Keith Institute, Ruth Wheal Room KEITH

- Carbon in your farm business. Carbon Footprint, emission reduction & sequestration options
- Soil carbon in our landscape. Can we build soil carbon? Soil carbon baselines & testing
- Applying the data - Telemetry for weather, groundwater, soil moisture & salinity
- Soil pH trends across the Tatiara and Coorong. Impacts on yield & feed growth. Economic treatments to overcome acidity
- See the Bednar Terraland deep ripper delver incorporator with crumbling roller up close

Please visit https://www.coorong.sa.gov.au/council-services/coorong-tatiara-local-action-plan/soil-health-and-dryland-salinity to access Full Program

PRESENTERS:

Brian Hughes, Amanda Schapel & Andrew Harding
Land Management Consultants, PIRSA

Felicity Turner – Independent Advisor

Simon March – EarthServ Pty Ltd

Australian Government | National Landcare Program

LANDSCAPE SOUTH AUSTRALIA LIMESTONE COAST

This project is supported by the Limestone Coast Landscape Board, through funding from the Australian Government's National Landcare Program

COORONG DISTRICT COUNCIL

Tatiara the good country

Coorong Tatiara Local Action Plan

Soils, Carbon and Productivity – Mount Charles & Keith
Friday 29th of October 2021

9am - 1.30pm – including lunch

	Item	Speaker	Organisation	Time	Page
1	**START – Cavanagh's** **Corner Heron & Browns Road MOUNT CHARLES**			**9.00am**	
2	**Three soil pits across the landscape looking at limitations to plant growth –** *including salinity, pH, compaction, soil test interpretation and discussion*	Brian Hughes – Principal Land Management Consultant	PIRSA	**9.10am**	3 - 10
3	**Telemetry for weather, ground water, soil moisture, soil salinity**	Felicity Turner	Independent Advisor	**10.10am**	11 - 18
	GRAB MORNING TEA TO EAT ON THE ROAD	Drive to the Keith Institute – Heritage Steet Keith		**10.30pm**	
	KEITH INSTITUTE, Ruth Wheal Room – Heritage Steet - Keith			**10.50am**	
4	**Carbon in your farm business. Carbon Footprint, emission reduction & sequestration options – case studies,** **Soil carbon in our landscape. Can we build soil carbon? Soil carbon testing and baselines.**	Amanda Schapel Senior Land Management Consultant	PIRSA	**11.00am**	19 - 20
5	**Applying the data - Telemetry for weather, ground water, soil moisture, soil salinity**	Felicity Turner	Independent Advisor	**11.50am**	11 - 18
6	**Soil pH trends across the Tatiara and Coorong** **Impacts on yield and feed growth** **Best bet treatments to overcome acidity**	Andrew Harding Senior Land Management Consultant	PIRSA	**12.15pm**	21 - 30
	LUNCH PROVIDED **END** **EVALUATION FORM / QR CODE PLEASE**	Learn about Bednar Terraland over lunch	Simon March Earthserv Pty Ltd	**1.00 – 1.30pm**	

.
Brian Hughes – Principal Land Management Consultant, PIRSA

General Description:

Grey sand over light clay and lime grading to yellowish brown sand
Watertable at 70cm

Landform: Plain, lower slope, dunefield in distance

Substrate: Molineaux sand over Padthaway formation (old coastal lagoons with deposits of clays, sands and limestone)

Vegetation: Tall wheat grass, phalaris and lucerne

Land use: Grazing – near weather station

Site Details:				
Site No:	3		Easting:	0418607
Hundred:	Laffer		Northing:	6010299
Sampling date:	9/7/21		Annual rainfall:	450 mm

Soil Description

Depth (cm)	Horizon	Description
0-15	A1	Very dark grey loamy sand. Abrupt to:
15-30	A2	Brown slightly calcareous fine sandy light clay. Clear to:
30-70	B2	Pinkish white very highly calcareous coarse loamy sand. Gradual to:
70-110	B21	Light yellowish-brown sand. Sharp to:
110-120	B22K	Light grey light clay coarse sand. 10-20% segregations.

Government of South Australia
Department of Primary Industries and Regions

Summary of Properties

Drainage: Imperfectly drained, due to shallow clay and underlying watertable at 70cms

Fertility: Moderately low

pH: Alkaline surface to strongly alkaline in subsoil

Rooting depth: 30cms

<u>Barriers to root growth</u>

Physical: Sodic clay at 15cm with some dispersion

Chemical: High Boron at 15cm, toxic salt and chloride at 30cms

Water holding capacity: Top 30cms would have around 35 mm, with salt tolerant vegetation will increase

Seedling emergence: Slightly water repellence in surface

Workability: Easily worked

<u>Erosion potential</u>

Water: Very low

Wind: Low

Laboratory Data

Depth (cm)	pH H_2O	pH $CaCl_2$	NO3 mg/kg	EC 1:5 dS/m	ECe	OC %	PBI	Colwell		Boron mg/kg	SO_4-S mg/kg	Trace Elements mg/kg (DPTA)			
								Avail. P mg/kg	Avail. K mg/kg			Cu	Zn	Fe	Mn
0-15	8.4	7.9	6.2	0.11	2	1.11	15	24	140	2.2	8.9	0.12	0.4	2.6	1.3
15-30	9.5	8.8	<1	0.57	5	0.43	88	12	610	20	36	0.19	0.26	10	0.5
30-70	9.3	8.8	<1	2.5	38	0.26	210	5	300	16	190	0.15	0.14	6.5	0.4
70-110	9.0	8.6	<1	1.4	21	0.06	23	<5	120	1.8	110	0.09	0.31	2.5	0.5
110-120	8.8	8.4	<1	1.8	27	0.08	223	<5	150	1.8	150	0.21	0.47	5.2	0.5
Critical / Ideal values	6-8	5-7	-	<0.7	<4	S: 0.5-1.0 SL: 0.7-1.4 L: 0.9-1.8 CL/C: 1.2-2.0	20-120	25-30	100	<15	>6-8	0.3	0.5		1

Depth (cm)	Cl mg/k	Sum cations cmol (+)/kg	Exchangeable cations cmol (+)/kg				ESP	Dispersion		Calcium carbonate Equiv %
			Ca	Mg	Na	K		2 hrs	20 hrs	
0-15	14	8.5	6.59	1.65	0.0	0.21	0	0	0	1.7
15-30	270	9.6	3.71	3.73	1.33	0.80	14	2	2	<0.4
30-70	3200	14.2	6.42	6.23	0.99	0.57	7	0	0	21
70-110	2100	4.5	2.32	1.98	0.07	0.17	2	0	0	1.8
110-120	2500	8.2	3.93	3.81	0.18	0.27	2	0	0	9.5
Critical / Ideal values	S: <120 L: <200 C: <300	15	75% of CEC	20% of CEC	<6% of CEC	5% of CEC	<6			

General Description:

Sand over clay with increasing lime over deeper sandy deposits

Landform: Plain, slight rise, good area

Substrate: Molineaux sand over Padthaway formation (old coastal lagoons with deposits of clays, sands and limestone)

Vegetation: Lucerne, annual grasses

Land use: Grazing

Site Details:

Site No:	4	Easting:	0418617
Hundred:	Laffer	Northing:	6010304
Sampling date:	9/7/21	Annual rainfall:	450 mm

Soil Description

Depth (cm)	Horizon	Description
0-10	A1	Brown loamy sand. Clear to:
10-19	A2	Bleached light brownish grey sand. Sharp to:
19-32	B21	Light yellowish brown highly calcareous sandy light clay. Clear to:
32-48	B22	Reddish yellow very highly calcareous light clayey sand. 2-10% calcareous segregations, 6-20 mm in size. Clear to:
48-90	B23K	Light grey very highly calcareous coarse clayey sand. 10-20% nodules, >60 mm in size. Clear to:
90-105	C1	Light yellowish-brown loamy sand. Gradual to:
105-120	C2	Light yellowish-brown sand.

Government of South Australia
Department of Primary Industries and Regions

Summary of Properties

Drainage: Well drained

Fertility: Very low inherent fertility in topsoil layers with low CEC values

pH: Akaline surface to strongly alkaline at depth

Rooting depth: 32cm before salinity becomes high

<u>Barriers to root growth</u>

Physical: Some root restrictions due to bleached A2 and B horizon, high ESP/dispersion at 19cms

Chemical: High Boron, pH at 19cms, high salinity and chloride at 32cms

Water holding capacity: Using 32cm WHC is 33.4 mm, salt tolerant plants will go deeper

Seedling emergence: Water repellent surface

Workability: Easily worked

<u>Erosion potential</u>

Water: Very low

Wind: Low

Laboratory Data

Depth (cm)	pH H_2O	pH $CaCl_2$	NO3 mg/kg	EC 1:5 dS/m	ECe	OC %	PBI	Colwell Avail. P mg/kg	Colwell Avail. K mg/kg	Boron mg/kg	SO_4-S mg/kg	Trace Elements mg/kg (DPTA) Cu	Zn	Fe	Mn
0-10	8.1	7.5	12	0.14	2	1.02	11	11	58	1.2	10	0.19	0.95	6.2	1.1
10-19	9.0	8.3	1.4	0.094	1	0.16	5	<5	45	0.83	5.6	0.1	0.14	1.6	<0.3
19-32	9.6	9.0	1.8	0.83	7	0.35	120	<5	480	25	41	0.19	0.1	11	<0.3
32-48	9.4	8.9	3	2.1	32	0.37	324	8	380	28	190	0.15	0.09	6.1	0.3
48-90	9.2	8.8	4.2	2.1	32	0.22	178	5	240	9.6	180	0.12	0.08	3.9	<0.3
90-105	8.9	8.6	3.2	1.7	26	0.1	19	<5	210	3	110	0.11	<0.08	3.6	<0.3
105-120	9.0	8.7	1.8	1.6	24	0.08	11	<5	130	2.1	110	<0.08	<0.08	2	<0.3
Critical / Ideal values	6-8	5-7	-	<0.7	<4	S: 0.5-1.0 SL: 0.7-1.4 L: 0.9-1.8 CL/C: 1.2-2.0	20-120	25-30	100	<15	>6-8	0.3	0.5		1

Depth (cm)	Cl mg/k	Sum cations cmol (+)/kg	Exchangeable cations cmol (+)/kg Ca	Mg	Na	K	ESP	Dispersion 2 hrs	Dispersion 20 hrs	Calcium carbonate Equiv %
0-10	46	4.9	3.73	1.07	0.00	0.08	0	0	0	<0.4
10-19	58	1.4	0.85	0.50	0.00	0.07	0	0	0	<0.4
19-32	430	12.5	4.61	5.37	1.58	0.89	13	2	3	4.8
32-48	2500	19.1	7.71	8.52	2.00	0.82	10	0	0	28
48-90	2600	12.5	6.05	5.18	0.73	0.49	6	0	0	17
90-105	2200	5.4	1.60	3.06	0.33	0.43	6	0	0	<0.4
105-120	2200	3.6	1.08	2.23	0.10	0.21	3	0	0	<0.4
Critical / Ideal values	S: <120 L: <200 C: <300	15	75% of CEC	20% of CEC	<6% of CEC	5% of CEC	<6			

General Description: Saline black clay over calcrete overlying deeper sandy and calcareous sediments

Landform: Plain, hollow within saline area

Substrate: Molineaux sand over Padthaway formation (old coastal lagoons with deposits of clays, sands and limestone)

Vegetation: Sea barley grass, edge of bare area

Land use: Grazing

Site Details:				
	Site No:	5	Easting:	0418567
	Hundred:	Laffer	Northing:	6010293
	Sampling date:	9/7/21	Annual rainfall:	450 mm

Soil Description

Depth (cm)	Horizon	Description
0-10	A1	Black highly calcareous light clay
10-20	B1k	Light brown very highly calcareous coarse sandy clay. 20-50% calcareous segregations, 2-6 mm in size.
20-28	B2k	Light grey very highly calcareous coarse sand. 20-50% calcareous segregations, 6-20 mm in size.
28-55	2B1	Gray sand.
55-70	2B22	Pinkish grey sand.
70-78	2B23	Greyish brown fine sandy light clay.
78-100	2B24K	Reddish yellow moderately calcareous coarse light clay. 20-50% calcareous segregations, <2 mm in size.
100-120	2B25K	Pinkish grey highly calcareous coarse light clay. 10-20% calcareous segregations, 2-6 mm in size.

Summary of Properties

Drainage:	Imperfectly drained, water table at 50cms
Fertility:	High CEC, organic carbon and nutrients levels however salinity issue at surface
pH:	Strongly alkaline to alkaline throughout
Rooting depth:	Salt tolerant species could possibly get to watertable at 50cm

<u>Barriers to root growth</u>

Physical:	Shallow water table, high ESP although did not disperse due to salinity which overides
Chemical:	Saline and high Boron on surface, high Chloride at 10cms
Water holding capacity:	Not relevant
Seedling emergence:	Ok if not saline
Workability:	Not relevant

<u>Erosion potential</u>

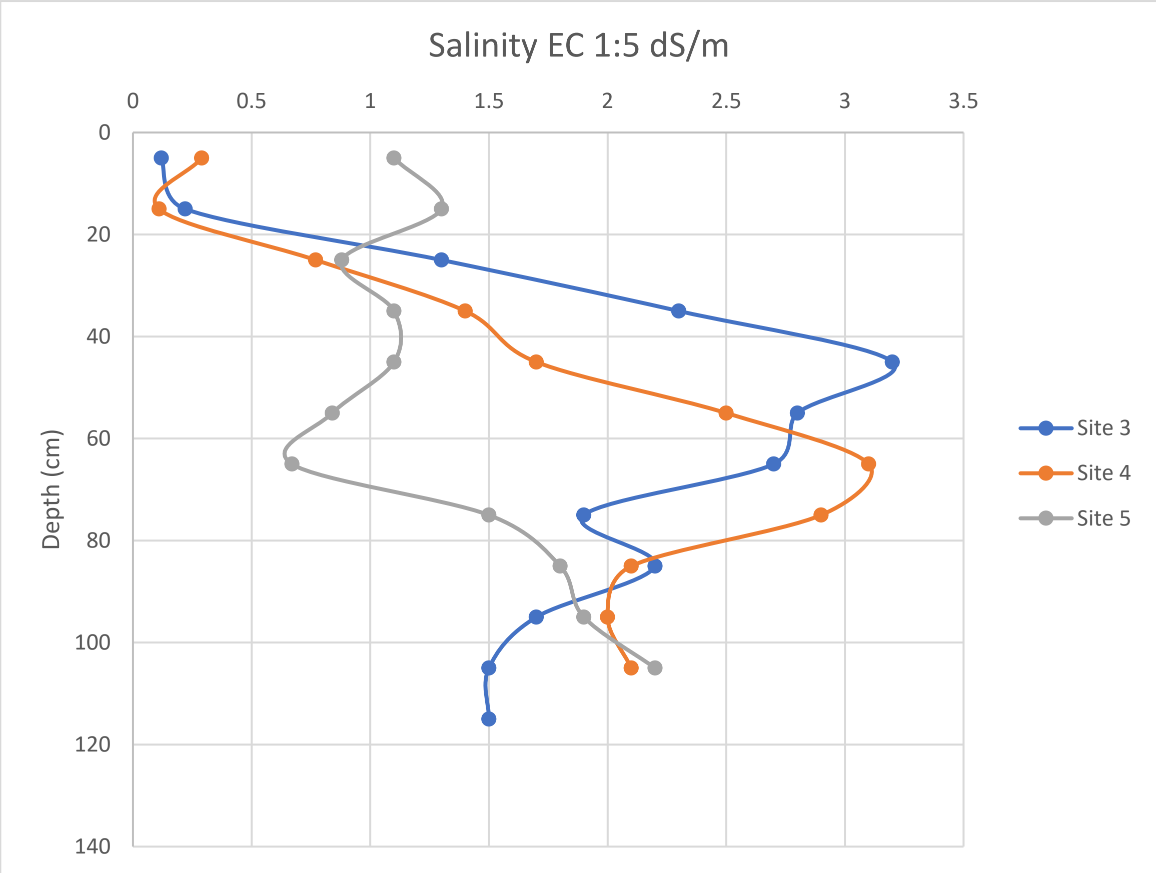
Water:	Moderate near drainage line
Wind:	Low

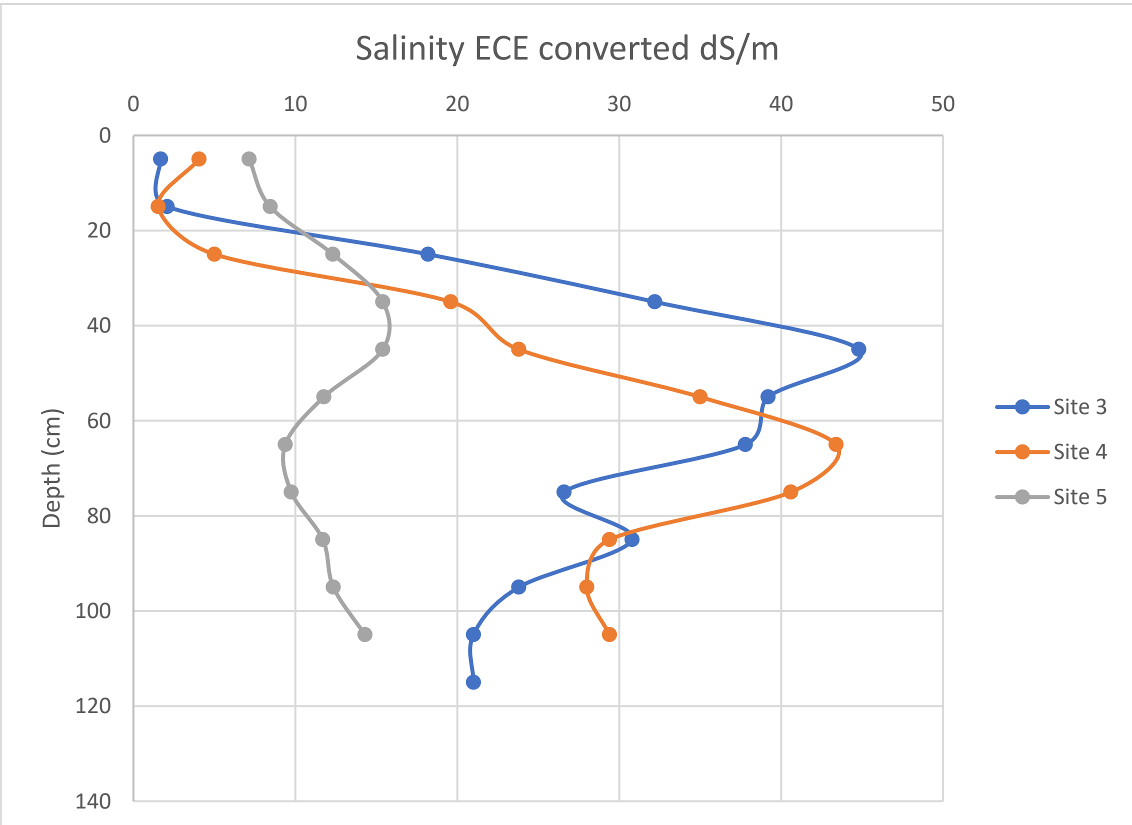
Laboratory Data

Depth (cm)	pH H_2O	pH $CaCl_2$	NO3 mg/kg	EC 1:5 dS/m	ECe	OC %	PBI	Colwell		Boron mg/kg	SO_4-S mg/kg	DPTA Trace Elements mg/kg			
								Avail. P mg/kg	Avail. K mg/kg			Cu	Zn	Fe	Mn
0-10	9.2	8.5	5.4	0.82	7	3.99	274	120	570	47	110	0.42	0.56	3.3	4.4
10-20	9.6	8.7	1.5	0.84	7	1.05	336	17	220	29	110	0.21	0.16	1.7	1.5
20-28	9.6	8.7	1.3	0.85	13	0.52	418	5	160	16	110	0.1	0.1	1.9	0.5
28-55	9.7	9.0	<1	0.78	12	0.06	28	<5	160	5.4	81	<0.08	<0.08	3.1	<0.3
55-70	9.3	8.9	<1	0.76	11	<0.05	11	<5	110	3.1	54	<0.08	<0.08	1.2	<0.3
70-78	9.1	8.5	<1	1.3	10	0.06	31	<5	490	8.5	120	0.12	0.08	5.7	<0.3
78-100	9.0	8.4	<1	1.8	14	0.15	160	<5	390	6.3	150	0.51	0.11	4.2	<0.3
110-120	8.8	8.3	1.1	2.6	21	0.15	131	<5	480	6.7	280	0.67	0.14	4.8	<0.3
Critical / Ideal values	6-8	5-7	-	<0.7	<4	S: 0.5-1.0 SL: 0.7-1.4 L: 0.9-1.8 CL/C: 1.2-2.0	20-120	25-30	100	<15	>6-8	0.3	0.5		1

Depth (cm)	Cl mg/k	Sum cations cmol (+)/kg	Pre-wash Exchangeable cations cmol (+)/kg				ESP	Dispersion		Calcium carbonate Equiv %
			Ca	Mg	Na	K		2 hrs	20 hrs	
0-10	210	30.3	13.3	11.5	1.3	4.21	14	0	0	37
10-20	340	15.9	7.81	5.26	0.42	2.42	15	0	0	77
20-28	540	12.5	6.38	4.23	0.28	1.59	13	1	1	62
28-55	770	3.9	1.85	1.69	0.24	0.09	2	0	0	0.8
55-70	880	2.5	1.04	1.24	0.15	0.03	1	0	0	<0.4
70-78	1600	10.3	2.58	5.41	0.94	1.33	13	0	0	3.6
78-100	2300	18.3	5.32	9.13	0.86	3.03	17	0	0	57
110-120	3100	23.2	5.89	11.5	1.2	4.65	20	0	0	39
Critical / Ideal values	S: <120 L: <200 C: <300	15	75% of CEC	20% of CEC	<6% of CEC	5% of CEC	<6			

SALINITY AT 10cm INTERVALS – Site 3 weather station, site 4 uphill, site 5 salt area





Felicity Turner – Independent Advisor

USE OF REMOTE MONITORING SYSTEMS

to improve knowledge and decision making around dryland salinity management

REPORT PREPARED BY FELICITY TURNER FOR THE COORONG TATIARA LAP

Key Points:

- **Be aware of which process is causing dryland salinity in your patch, as this will need to be factored in when making management decisions**
- **The use of real time data has improved land manager confidence in the management of dryland salinity**

Background

After decades of successful management and drier years, regional dryland salinity is slowly increasing across the Coorong District Council region with large areas believed to be at risk of becoming saline in the coming years.

Since 2016, the Coorong Tatiara Local Action Plan (CTLAP) has been conducting work on new and historic saline sites to remediate these areas, and reduce the total area of degradation caused by dryland salinity. Where successful, remediation and recharge reduction has provided groundcover and reduced the amount of soil erosion occurring on these areas. Programs undertaken by the Coorong Tatiara Local Action Plan have provided opportunities to explore what is and isn't working in the management of local dryland salinity management systems. As part of this work, several observations have been made by farmers around the conditions that appear to improve results when remediating soils. In particular, the 'flushing effect' required by natural rainfall events and the importance of groundcover in these systems.

Fig 1. Shane Oster, Alpha Group Consulting installing automated weather station and probe at Elephant Lake, 2020

PROJECT DETAILS

Project ID: nbn00001

Funding Body

This project was funded through Landcare Australia by a NBN Co Sustainable Agriculture Landcare Grant

Project Duration

2020-21

Site Locations

Coomandook, Meningie East, Mount Charles

The opportunity arose to utilise automated monitoring equipment to test these observations by using automated monitoring equipment to measure the depth of the water table, soil moisture levels, soil salinity levels and environmental conditions in real time at three monitoring sites across the Coorong and Tatiara District Council regions. This data is updated via automated telemetry every 15 minutes and both real time and historical data can be viewed utilising the internet. These sites have been selected as they are viewed as 'transient' saline sites.

Initial findings from the information being generated suggest that there are two very different dryland salinity processes that are occurring across the region (even within relatively close proximity of each other). It is hoped that additional funding can be sourced to expand monitoring sites and continue the interpretation of this data into the future allowing farmers to make more informed decisions when managing saline areas (particularly those that are transient and scald one year, but may be back into production in the following year).

It is hoped that this technology can be expanded to the mitigation phase; improving our understanding of crop and pasture water use in the landscape and how much rainfall is effectively used compared with what travels through the profile and recharges into the groundwater system.

Interpreting soil moisture probe data

- ### Summed graphs

The summed graphs provide information around the total amount of water in the profile at any point in time. Where soil moisture probes have been in for several years (>5) e.g. soil moisture probe at Pine Hill[1] (Figure 2), we have built up an understanding around the "wettest point" – as close to full capacity as has been observed and the "driest point" observed – beyond which the crop or pasture can't extract any additional moisture. The difference between the wettest point and driest point is the maximum amount of water available to the plant within the observed depth (in this case 90 cms). This maximum amount of water should be thought of as % full as opposed to absolute numbers.

Figure 2. Summed soil moisture data at Pine Hill (2016)

- ## Stacked graphs

The stacked graphs provide information around where in the profile the soil water is located. Understanding how deep into the profile water moves after a rainfall event, at what depth plants are accessing moisture from and where the moisture is stored are all useful pieces of information that provide a lot more value when compared to the stacked graphs (and total amount of soil water available) alone.

The stacked graphs also can provide useful information around where the water is coming from; is it coming from rainfall events or the water table, is the water table rising or falling and knowing the potential impact that has on your system with regards to root growth can also aid in more informed decisions being made.

Figure 3 shows a summed graph from the Mount Charles site where it can be seen that a rainfall event in late May has pushed the soil moisture down to 20cms, with the next major rainfall event on the 16th June pushing the moisture down to 30cms.

Crop extraction at a certain depth will be represented by diurnal stepping (where the sensor drops during the day while the crop is extracting moisture and then flattens at night).

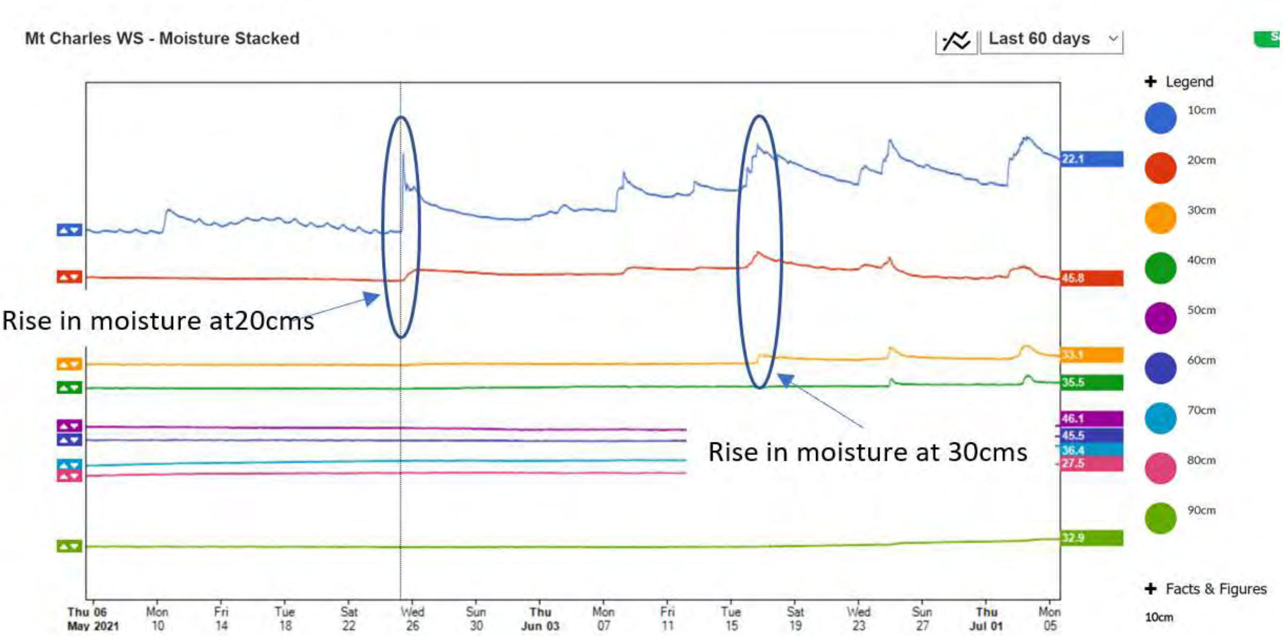


Figure 3. Stacked soil moisture at Mount Charles (June 2021)

What processes are we observing at sites across the Coorong and Tatiara District?

The equipment was installed in September and October 2021. Therefore we have limited data available with a full season at all of the observation sites yet to be collected. However given this small time-frame, we are seeing some really interesting data being generated.

There appears to be two very distinct processes occurring – possibly related to the location of the sites in the landscape, but the initial findings have already Improved knowledge around the different processes and therefore what mitigation strategies may be best put in place for each of these sites.

- ## Rising water table

Mount Charles and Elephant Lake both appear to be sites that are impacted directly by a rising water table that brings groundwater closer to the surface with the potential for soil inundation and waterlogging to occur. The water table then recedes later in the season leaving some of the dissolved salts from the saline groundwater behind. This process can be seen in Figure 4 where the observation site at Elephant Lake shows the increase in the water table in mid-June and a subsequent filling of the soil profile from the bottom up. The black line represents the water table depth and as it rises from -1.4m below surface depth to -0.7 below surface depth, the soil moisture also increases at depth with the soil moisture levels increasing up the profile through the wetting front. This process has been referred to as rising water table. A similar pattern appears to be emerging at Mount Charles (although not yet as pronounced) where the water table has just started to rise in June 2021. This will continue to be monitored to ensure that the correct process is identified at this site.

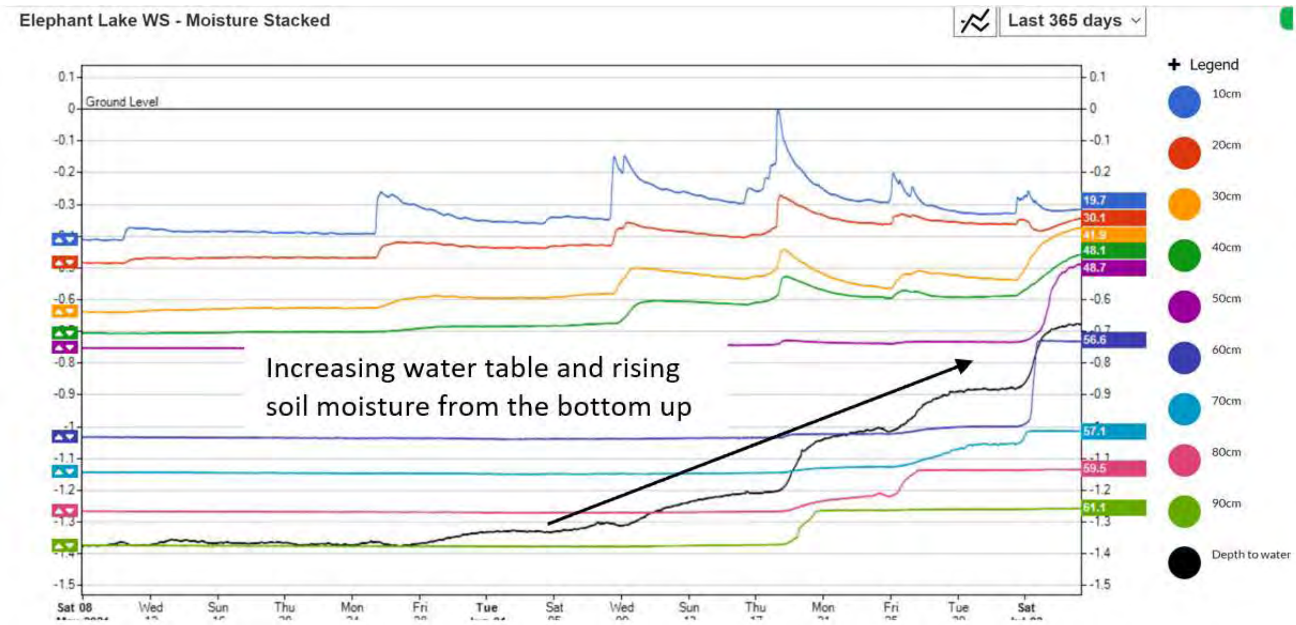


Figure 4. Stacked soil moisture and water table data, Elephant Lake (June 2021)

- ## Wicking effect

Coomandook has a very different process occurring with the water table appearing to be relatively stable throughout the season (although this is only an initial finding that will continue to be monitored). The salinity at this site appears to be driven by warm conditions over summer and wicking of the soil moisture up through the profile (in the event of no rainfall or rising water table events). This is shown in Figure 5 and is referred to as the Wicking Effect (a similar process to wax or oil moving up a candle wick). As the water rises to the surface, it brings with it salts that are deposited as the profile dries out. As more data is collated, it will be interrogated against climatic conditions, and the overall processes will become better understood. The depth that the soil water is rising from is quite surprising, but after installation the site may have been bared out slightly at the surface with the disturbance from the probe placement. As groundcover is re-established at this site, it is hoped that the wicking effect will not be as pronounced.

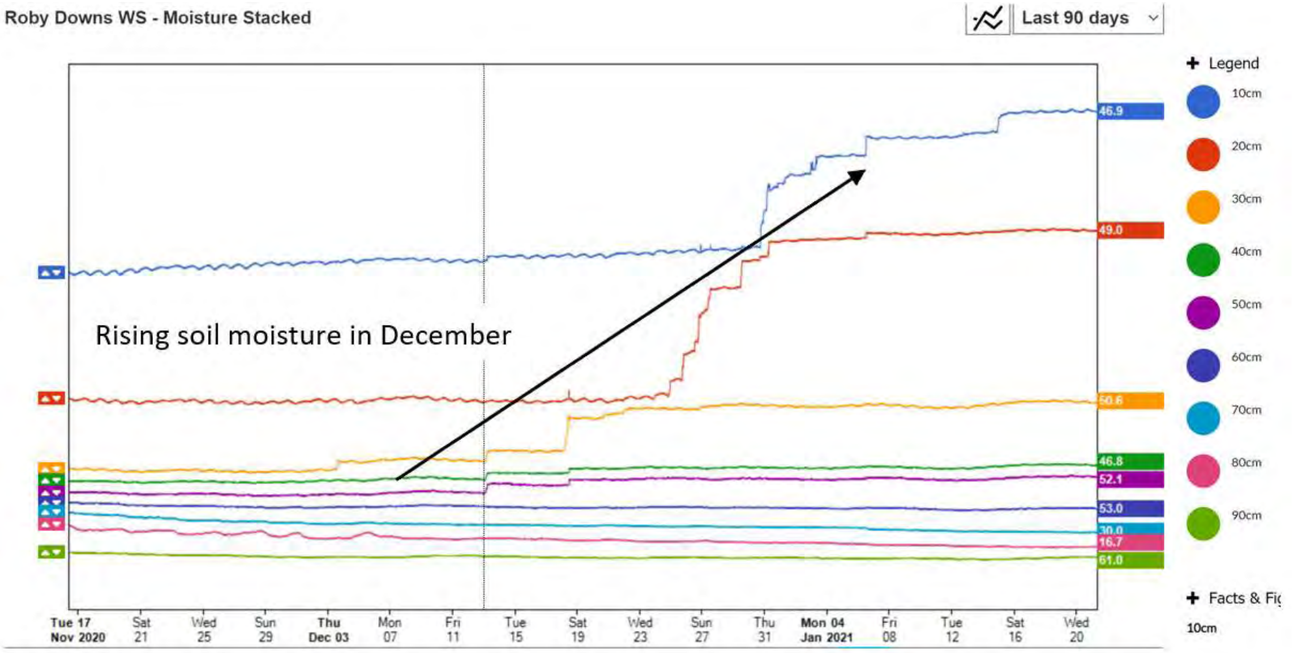


Figure 5. Stacked soil moisture graph, Commandook (December 202)

Environmental data

Additional data being collected includes rainfall, wind speed and direction, air temperature, soil temperature and relative humidity as well as other environmental derivatives (Figure 6). It is hoped that as more data is collected some of these indicators like soil or air temperature may be linked to the wicking of water through the soil allowing the data to be transferrable across to other locations.

Figure 6. Environmental data being collected at Mt.Charles

Dashboard of implications for management

Initial findings suggest that knowing the cause of salinity (waterlogging or wicking) has the potential to have implications on the way that the site is remediated and managed. More work is required on understanding how widespread each of the different processes (wicking or waterlogging) are, and if the different processes operate within a local catchment area or if it depends on the location of the site in the landscape.

If groundwater is rising from below the ground, then ensuring groundcover is established early before the area becomes too wet will assist in establishing and maintaining groundcover and potentially reducing the area that becomes scalded. It may also be beneficial to minimise stock numbers over the period that the water table is high to reduce pugging, damage to groundcover and soil structure.

Conversely, those areas that experience wicking will need water to flush down through the profile to reduce the salt concentration prior to establishment. At these sites, knowing that the water table is at depth, there may be the opportunity to look at ripping to assist in providing a passage for the salts to flush through, however once this has occurred, maintaining groundcover to reduce wicking and evapotranspiration over summer will be critical.

The depth from which the groundwater is wicking over summer was also surprising, as it rose over 1m on what is a loamy soil. Further investigation may be required to determine the maximum height that the water will rise to on these soils and explore what is happening on sites that are more slightly elevated in the landscape to see if the process changes.

As the data continues to be collected, it is hoped that in consultation with farmers and the Saltland Redemption Project Working Group, that more recommendations around management options utilising this technology will be made.

Conclusion

From the data that has been generated since the projects inception (September 2020) there appears to be some really interesting relationships between soil moisture, soil salinity through the profile and its relationship with the groundwater with some sites (Elephant Lake) having strong correlations, and another (Coomandook) appearing to have little or no relationship with the groundwater levels.

As more data is collected, it is hoped that the environmental data (in particular temperature - both ambient and soil, and rainfall) may provide additional insight into how these factors impact on the movement of water and salts through the profile. The late start to the season, and moisture only just starting to move through the profile suggest that it will be later in the season that we start to get an indication of the impacts of rainfall etc. on the soil salinity levels.

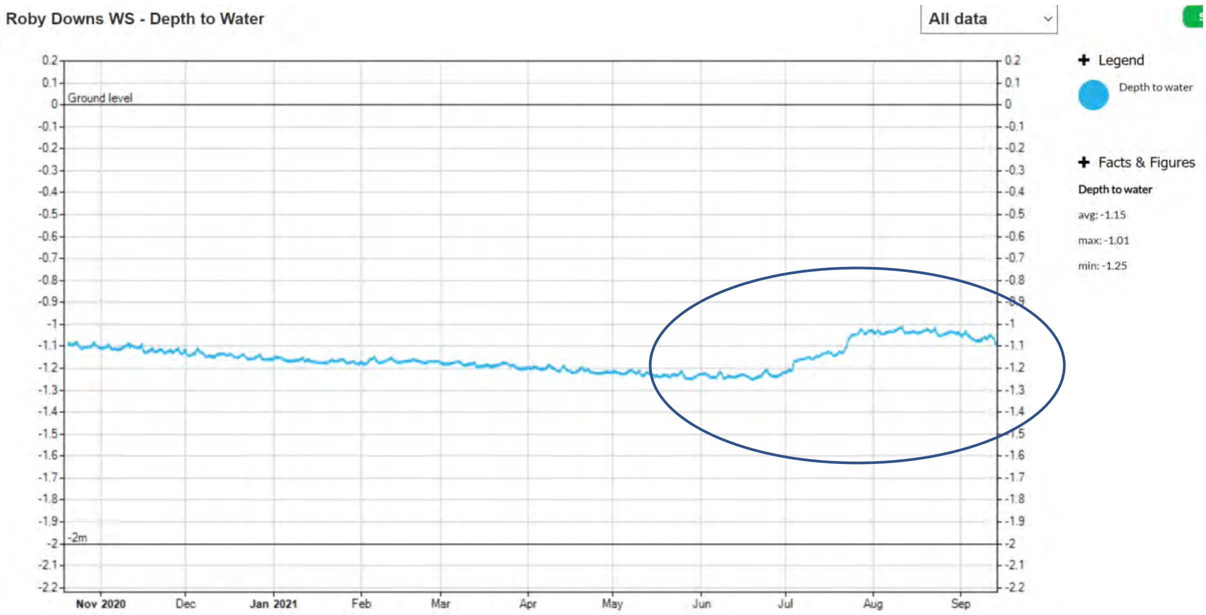
As these relationships become clearer, it is hoped that farmers will utilise the data to make better decisions to reduce the impacts of salinity across the region. Waiting until the salts are observed to have flushed from the topsoil (or alternatively seeing moisture move through the profile) will ensure better germination on transient sites. Knowing when the soil is starting to become waterlogged on those sites where the water table is rising will ensure that groundcover is maintained at those times so that scalding doesn't occur.

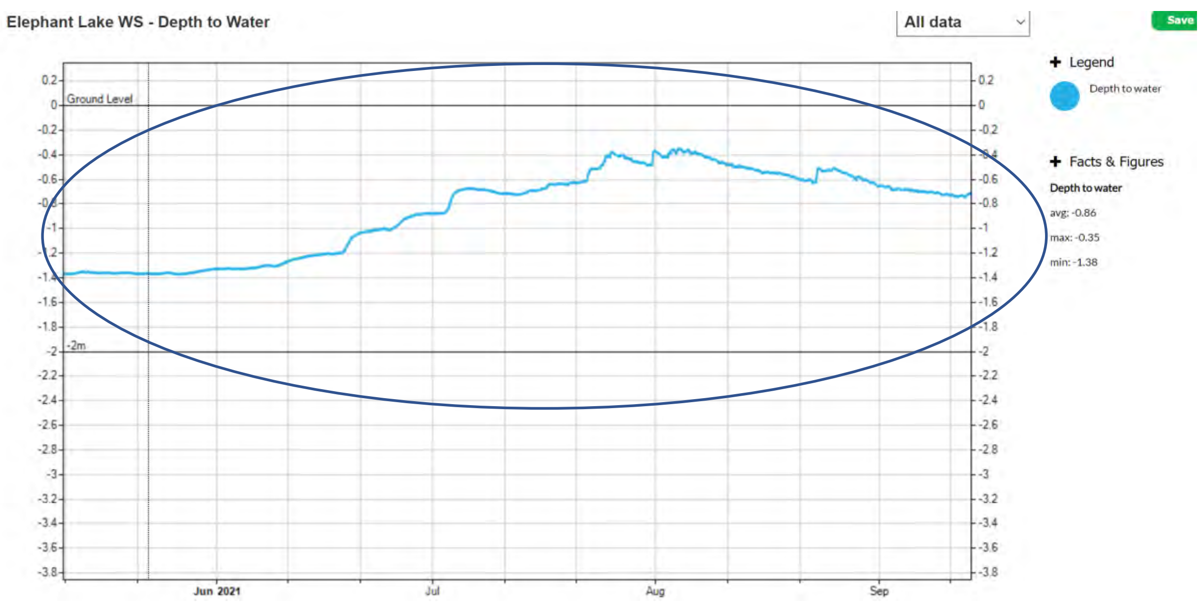
References

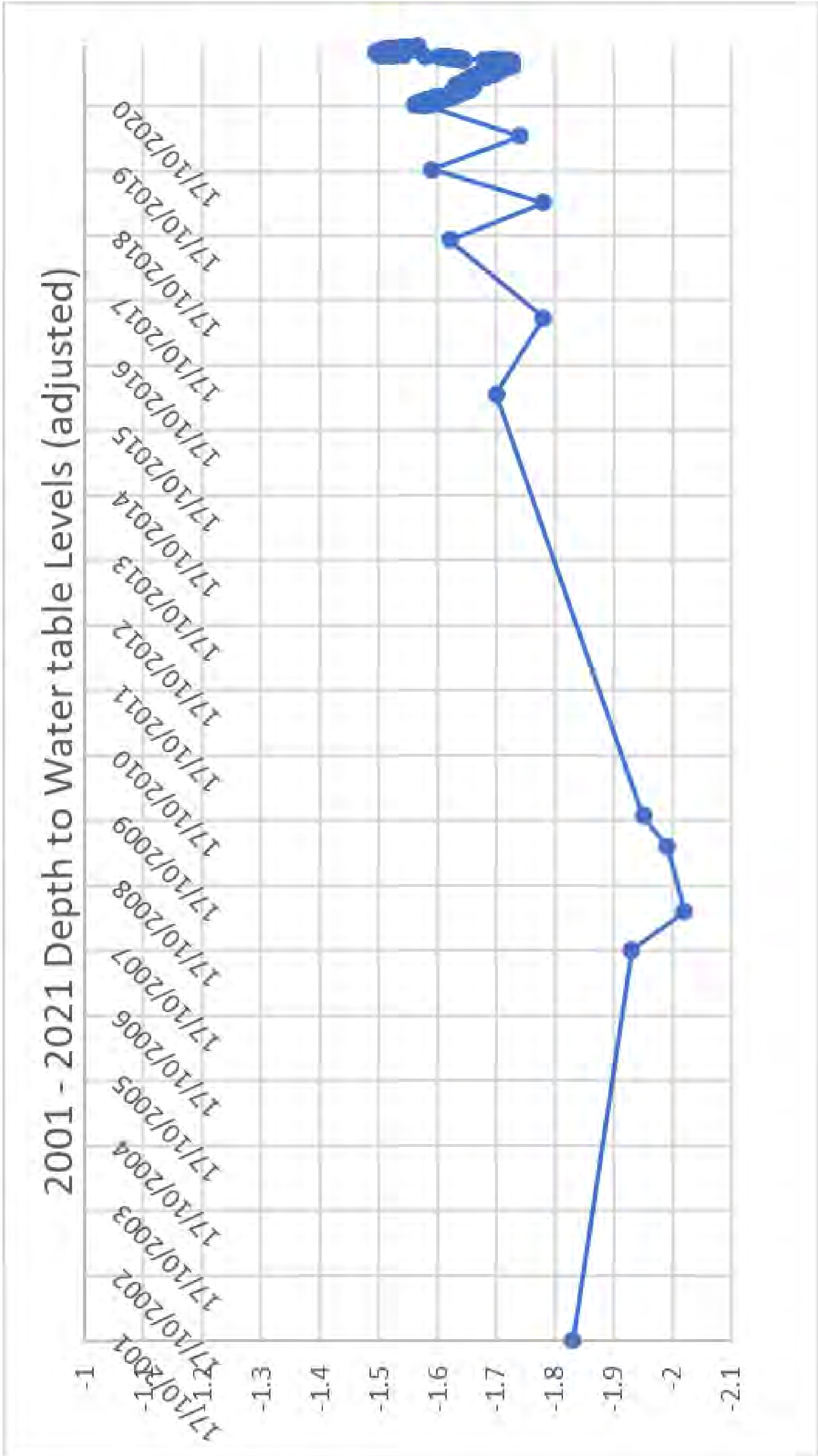
[1] F.Turner, MacKillop Farm Mangement Group, 2021. SAGIT MFM_218 "Utilising soil moisture probes in dryland cropping systems"

This project was funded through Landcare Australia by a NBN Co Sustainable Agriculture Landcare Grant and is an initiative of the Meningie East-Field Healthy Soils Group with support from the Coorong and Tatiara District Councils.

Water Table – automated piezometer readings






2001 - 2021 Depth to Water table Levels (adjusted)
-1
-1.1
-1.2
-1.3
-1.4
-1.5
-1.6
-1.7
-1.8
-1.9
-2
-2.1
17/10/2001
17/10/2002
17/10/2003
17/10/2004
17/10/2005
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17/10/2020

Amanda Schapel – Senior Land Management Consultant, PIRSA

Soil Carbon in SA Agricultural Soils

Soils, Carbon and Productivity Workshop - Keith

Role of organic carbon in the soil

Physical	Chemical	Biological
better structural stability (aggregation) lower bulk density rapid infiltration of water better drainage better root growth less erosion improved water holding capacity	improved cation exchange source of nutrients continual release of nutrients sorption and deactivation of contaminants	increased biological activity increased diversity improved suppression of soil borne pathogens

Soil Carbon Tests

Test	Method	Measures	Benefits/Limitations
Organic C	Wet oxidation (Walkley Black method) **6A1**	OC	Incomplete reaction – measures 75-90% of Total OC. Doesn't measure carbonate which can be a benefit.
Total Organic C	Wet oxidation (Heanes method) **6B1**	OC	Total OC test by wet oxidation due to an external heating step. Does not measure carbonate.
Total C	High temperature combustion (Dumas) **6B2b**	OC and IC	Measures Total OC in acid or neutral soils. In soils with carbonate and charcoal can be difficult to measure change in OC
Total Organic C	Acid pre-treatment then high temperature combustion (Dumas) **6B3**	OC	Preferred method for soils with carbonate present. Need to ensure that have complete removal of carbonate before combustion or results will be incorrect.
Inorganic C	Calcium carbonate Equivalent **19A1**	IC	Measures the carbonate by reaction to dilute HCl acid. Can be an inexact test.
Mid Infrared	Spectroscopy **6B4b**	OC and fractions	Quick and relatively cheap, not as accurate as other methods until calibrated. Sensitive to carbonate and requires acid pretreatment. Not commercially available in high pH soil.

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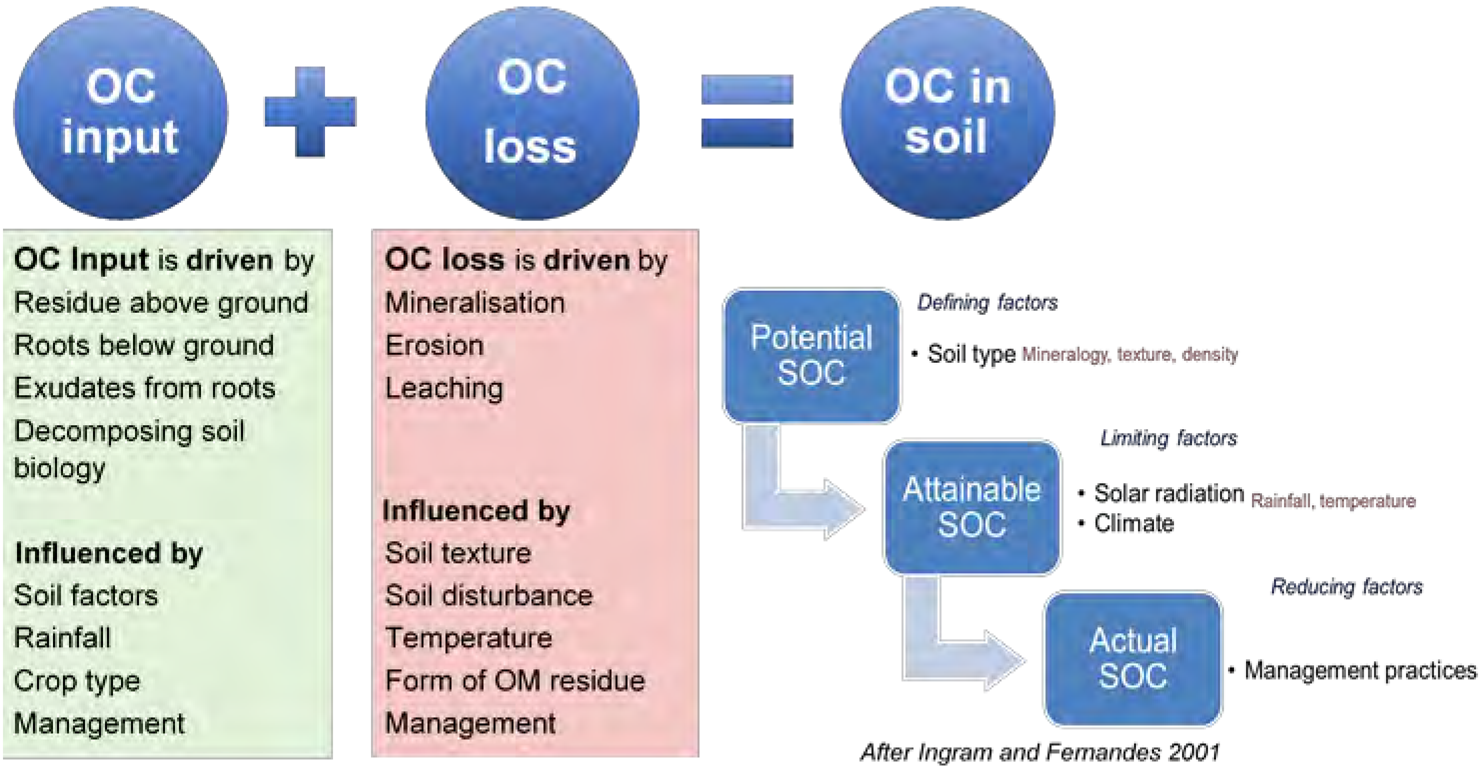
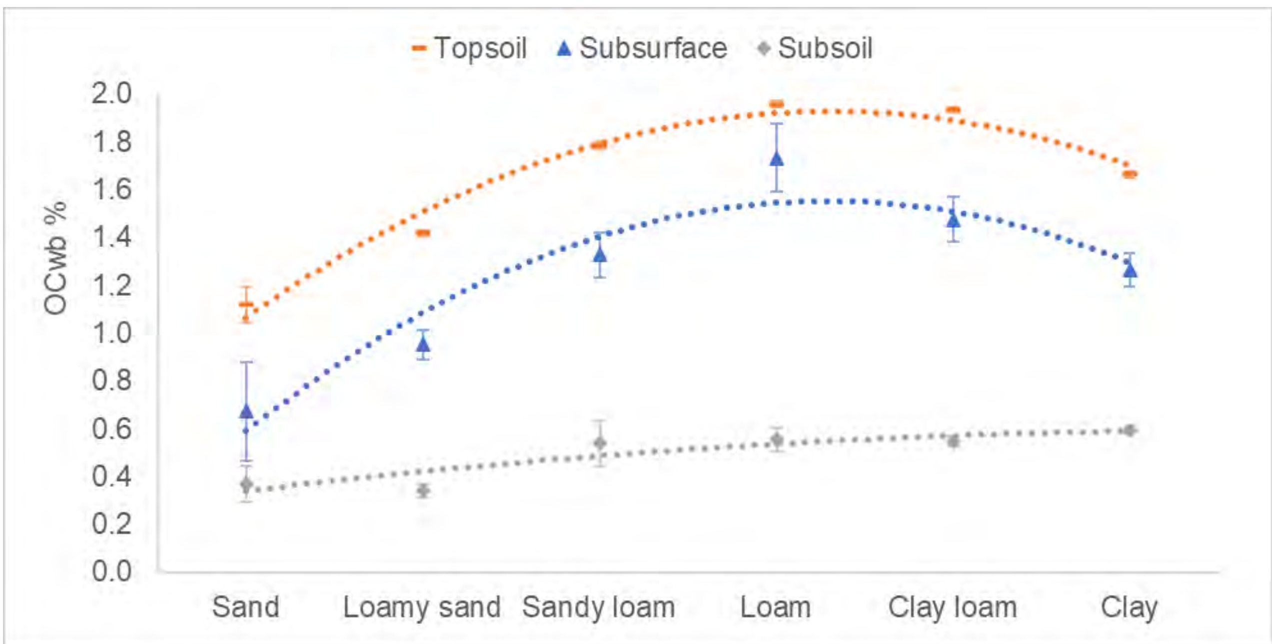
Factors that affect soil organic carbon (OC)



Average Organic Carbon Concentration of South Australia Agricultural Zone



Topsoil Organic Carbon guides for texture by key land uses for SA Agricultural soils

	Pasture			Cropping			Orchard / Vineyard		
	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
Sand	<0.9	0.9 - 1.6	>1.6	<0.6	0.6 – 1.1	>1.1	<0.6	0.6 - 1.5	>1.5
Loamy sand	<1.2	1.2 – 2.8	>2.8	<0.6	0.6 - 1.3	>1.3	<0.5	0.5 - 1.1	>1.1
Sandy loam	<1.9	1.9 – 3.8	**>3.8**	<0.9	0.9 - 1.3	**>1.3**	<0.6	0.6 – 1.5	**>1.5**
Loam	<2.2	2.2 – 4.1	>4.1	<1.0	1.0 – 1.7	>1.7	<0.7	0.7 – 1.8	>1.8
Clay loam	<2.0	2.0 – 4.2	>4.2	<1.2	1.2 – 1.8	>1.8	<0.8	0.8 - 2.0	>2.0
Clay	<1.8	1.1 – 4.2	>4.2	<1.2	1.2 - 1.7	>1.7	<0.8	0.8 – 2.0	>2.0
All textures	<1.7	1.7 – 3.8	>3.8	<1.0	1.0 – 1.7	>1.7	<0.7	0.7 – 1.8	>1.8

Topsoil Organic Carbon benchmarks for the Upper South East Agricultural District

Benchmark topsoil OC (%) values for texture and land use displaying the mean and percentile values for the Upper South East compared to the mean for the Agricultural Zone.

	Ag Zone	Ag District Benchmarks						
Texture	***Mean***	**Count**	**Mean**	**25%**	**40%**	**50%**	**60%**	**75%**
Sand	*1.12*	23	1.08	0.90	1.05	1.12	1.19	1.31
Loamy sand	*1.42*	933	1.21	0.85	1.01	1.10	1.24	1.51
Sandy loam	*1.79*	636	1.43	0.96	1.20	1.35	1.50	1.80
Loam	*1.96*	437	1.66	1.20	1.40	1.50	1.70	1.97
Clay loam	*1.93*	308	1.81	1.40	1.59	1.74	1.87	2.13
Clay	*1.66*	288	1.63	1.00	1.26	1.40	1.60	1.92
Weighted Mean (all texture)	*1.77*	2625	1.45	1.02	1.22	1.33	1.49	1.77

	Benchmark OC Concentration					District Prop (%)
Land use	**Count**	**Mean**	**25%**	**50%**	**75%**	
Orchard / Vineyard	235	0.98	0.58	0.87	1.30	12
Cropping	1084	1.50	1.06	1.43	1.86	54
Irrigated Pasture	20	1.54	1.10	1.41	1.86	1
Pasture	620	1.55	1.00	1.36	1.91	31
Vegetable	37	1.67	1.10	1.51	2.24	2

Tables extracted from 'Soil Carbon in South Australia: Volume 3 – Benchmarks and Data analysis for the Agricultural Zone 1990-2007'. Schapel A, Herrmann T, Sweeney S and Liddicoat C (2021).

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Soil acidity and treatment in the Coorong and Tatiara District Council areas

The extent, causes and treatment

KEY POINTS

- Soil acidity is becoming an emerging and significant issue throughout the Coorong and Tatiara District Council areas presenting a major constraint to crop and pasture production.
- Soil acidity can affect sub-surface and sub-soils.
- Soil pH should be tested in paddocks on a regular basis at 5 cm increments to at least 15 cm.
- Soil acidity can be treated with the use of lime and / or soil modifications (such as ripping, delving, spading and clay spreading) provided that the underlying clay has a neutral or alkaline pH.

Figure 1: Testing soil pH at a soil pit field day

Introduction

The Coroong and Tatiara District Council covers a combined area of 1.54 million hectares. It is a productive area of South Australia with a total value of annual agricultural production of about $490 million (ABS, 2015-16).

Soil acidity (low soil pH) is becoming an emerging and significant problem throughout this area particularly on the sandy to sandy loam textured soils. It is a natural process but is accelerated by more productive and intensive farming practices.

When soil pH falls below a pH of 5.5 ($CaCl_2$) the productivity of crops and pastures starts to decline.

The area of the Coorong and Tatiara District Council area, currently acidic or likely to become acidic in the next few years is approximately 334,500 hectares or 35.6% of the agricultural area with an estimated crop and pasture production loss of $5.8 million per year (Figure 2, Table 1).

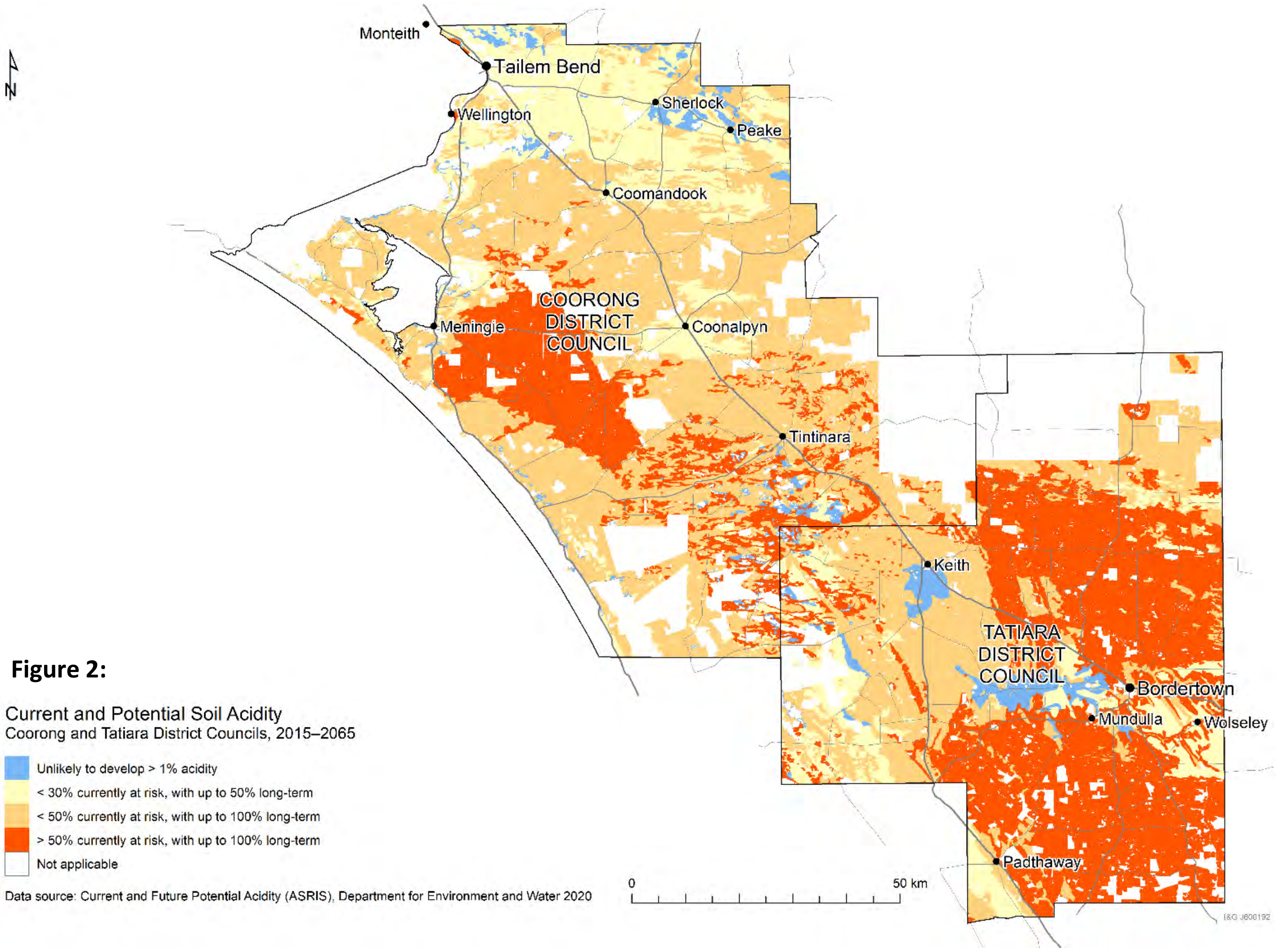


Figure 2:

Current and Potential Soil Acidity
Coorong and Tatiara District Councils, 2015–2065

Data source: Current and Future Potential Acidity (ASRIS), Department for Environment and Water 2020

Table 1: Area and total production loss due to soil acidity within each Council area.

	Coorong District		**Tatiara District**		**Total Coorong and Tatiara District**	
Total area	886,084 hectares		652,097 hectares		1.54 million hectares	
Annual agricultural Production (ABS 2015-16)	$247 million		$243 million		$490 million	
	Area impacted (ha)	Total production loss	Area impacted (ha)	Total production loss	Area impacted (ha)	Total production loss
Area currently affected by acidity	117,825	$1.9 million pa	216,690	$3.9 million pa	334,515	$5.8 million pa
Area that will be affected over next few decades	255,448	$3.9 million pa	119,666	$2.2 million pa	375,114	$6.1 million pa
Total	373,273	$5.8 million pa	336,356	$6.1 million pa	709,629	$11.9 million pa

It is estimated that a further 375,000 hectares of agricultural land in the area has the potential to become acidic over the next few decades assuming that the current farming practices continue and that soils are not adequately treated (Figure 2). This could result in an extra estimated crop and pasture production loss of $6.1 million per year (Table 1).

Lime and /or soil modifications such a ripping, delving, spading or clay spreading are options for the treatment of acid soils

Cause and effect of acid soils

Soil acidity is caused by a build-up of hydrogen ions throughout the soil due to:

- the accumulation of organic matter;
- addition of ammonium-based nitrogen fertilisers;
- nitrate leaching; and
- the large removal of alkaline nutrients in plant and animal products.

Increased use of nitrogen fertiliser, higher yielding crops and more intensive cropping rotations have increased the rate of acidification throughout many areas of the Coorong and Tatiara District and has extended the areas where soils were not previously affected.

Nitrogen fertiliser applications accelerate soil acidification. Sulphate of ammonia (SOA) is three times more acidifying than urea, and one-and-a-half times as acidifying as diammonium phosphate (DAP) when compared per unit of nitrogen.

If soil acidity is not treated and when the soil pH falls below 5.5 ($CaCl_2$) nutrients such as phosphorus, potassium, calcium, magnesium and molybdenum become less available to plants.

Figure 3 shows the influence of pH on nutrient availability (pH water). The width of the bars indicates the availability of nutrients at different pH levels. The wider the bar the more available the nutrient is.

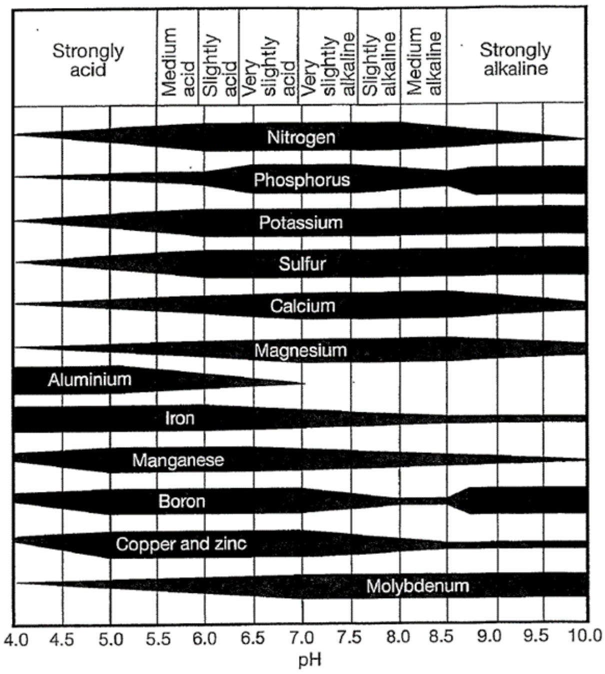


Figure 3: Influence of pH on nutrient availability (pH water) (Price, 2006)

Soil acidity can also reduce microbial activity including *Rhizobia* which are important for the nodulation of legumes. As the pH falls, toxic amounts of aluminium can be released into the soil, affecting root growth and plant development. Due to less availability of nutrients and toxic levels of aluminium then the productivity of crops and pastures start to decline, particularly for acid-sensitive plants resulting in a substantial economic loss.

Lucerne, lentils, annual medics, faba beans, canola and barley are all sensitive to acid soils. As the soils become more acidic, less sensitive crops may start to become affected. Table 2 shows the tolerance of crops and pastures to low soil pH.

Table 2: Tolerance of crops and pastures to soil acidity (low soil pH)

Very Sensitive	Sensitive	Tolerant	Highly tolerant
Lentils	Canola	Wheat*	Oats
Faba Beans	Phalaris	Sub-clover	Triticale
Chickpeas	Barley	Rye-grass	Lupins
Lucerne	Peas		Couch grass
Annual medics			
Durum wheat			
*Some wheat varieties can be sensitive while others can be tolerant. Wheat varieties that have some tolerance include: Wyalkatchem, Mace and Scepter.			

The symptoms of soil acidity show up as patchy un-even crop and pasture growth, yellowing of crops (Figure 4) poor nodulation of legumes and stunted root growth. If soil acidification is allowed to continue then it is likely that it will further decrease productivity and limit planting options to acid tolerant crops and pastures.

Acid tolerant weeds such as rye-grass and couch grass may dominate in areas where soils are acidic.

Figure 4: Symptoms of low soil pH on a Faba bean crop. Low soil pH 4.0 ($CaCl_2$), Good soil pH 5.5 ($CaCl_2$)

If soil acidification continues then sub-surface and sub-soil layers can also be affected which are much more difficult and expensive to treat.

Where plants are affected there can also be reduced plant water use that can contribute to rising water tables and increased soil salinity. Where areas are left bare or partially bare then sandy areas can be prone to wind erosion.

Productive farming practices will continue to acidify the extent and severity of acid soils unless adequate on-going treatment such as liming and / or some form of soil modification is implemented.

Soil sampling and testing

Soil pH can be measured in the field or in the laboratory. Field testing kits (Figure 5) that can be purchased from agricultural stores are a useful guide for measuring soil pH levels. However, the result is an approximation of pH measured in soil water.

For a more precise test, soil samples should be sent to a soil laboratory and tested for pH in calcium chloride ($CaCl_2$).

Figure 5: Field testing kits can provide a guide for measuring in-field soil pH levels (Credit: Belinda Cay, Ag Communicators).

Soil sampling was traditionally carried out by taking twenty or so soil samples at a depth of 0-10 cm in a transect across the paddock and then the soil samples were sent to a laboratory.

Many soils are often stratified where they have a thin alkaline layer with an acid layer below. By sampling soils at 10 cm deep, often the severity of soil acidity was missed. When taking soil samples, it is now recommended to take depths at 0-5 cm increments to a depth of about 15 to 20 cm and then send these samples to a soil laboratory. When taking soil samples ensure that they are from a uniform area i.e. similar landscape and soil type.

On the laboratory test results you will notice that soil pH is measured by two methods in soil water or calcium chloride ($CaCl_2$) The optimum plant growth for pH (water) is between 6 and 8.5.

Soil pH ($CaCl_2$) is now the preferred method for testing soil pH as it gives a more accurate result in neutral to acid soils. However, it is about 0.8 pH units lower than pH (water). All lime spreading recommendations are based on pH ($CaCl_2$).

For optimum crop and pasture production the soil pH ($CaCl_2$) in the top-soil should be 5.5 or greater.

Soil pH, NDVI and yield mapping

Precision soil pH mapping by machines is a relatively new technology for measuring and mapping soil pH variation across paddocks. There are now a number of soil sampling machines that are commercially available. This includes the Veris® machines and quad bikes or ATV's with sampling units.

The Veris® machines can be towed with either a tractor or 4WD. As they are towed across the paddock they take a sample on-the-go, measure the soil pH from direct contact and record its geographic position.

Figure 6: Veris® soil pH mapping machine

At a swath width of about 36 metres wide the machine samples about 8 to 10 points per hectare (Figure 6).

A number of organisations are now offering a soil sampling service where soil sampling units are mounted onto quad bikes or ATV's.

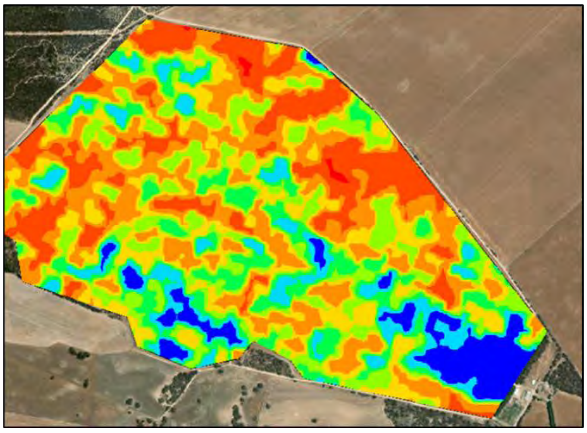
Soil sampling is carried out on a pre-determined geo-referenced grid basis, and due to cost-effectiveness, is generally done on a one to two hectare grid. The soil is then sent to a laboratory for a range of soil analysis.

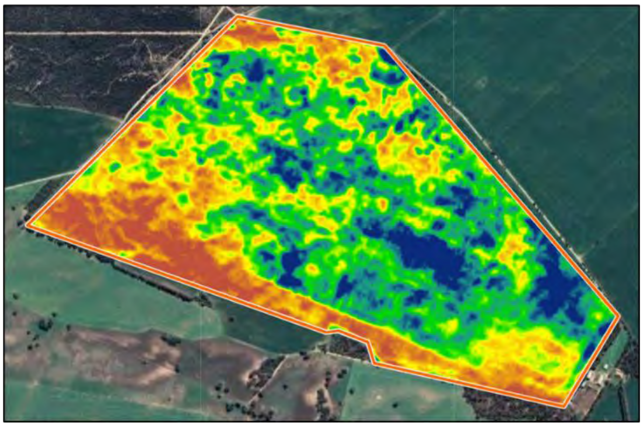
Once the data has been downloaded, pH maps can then be produced. The maps often show a large spatial variability of soil pH and identify pH zones across paddocks (Figure 7). The soil pH maps show where lime should be targeted, and appropriate liming rates can be calculated for each zone.

By applying lime only where it is needed rather than a 'blanket' application results not only in improved soil pH conditions across the paddock but also helps to save costs.

Normalised Difference Vegetation Index (NDVI) maps (from satellites) that measure plant health and biomass as well as yield maps can also be used as a guide for acid soils. If the maps are showing low NDVI or low yield and if other issues such as diseases, nutritional problems, weeds, soil types and other constraints (shallow soils, rockiness etc) are eliminated then soil pH maybe the underlying cause.

Figure 7 & 8 shows the correlation between a soil pH map and NDVI map for beans. Where the soil pH is low then the beans are not growing as well.





pH range	Area (ha)
7.500 - 8.200	11.73 ha
7.000 - 7.499	14.63 ha
6.500 - 6.999	21.70 ha
6.000 - 6.499	33.67 ha
5.500 - 5.999	37.24 ha
5.000 - 5.499	42.87 ha
4.500 - 4.999	27.03 ha
4.050 - 4.499	0.51 ha

Figure 7

Figure 8

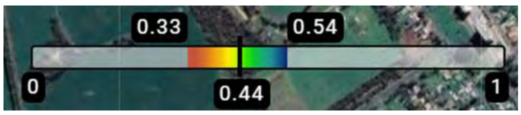


Figure 7: Soil pH Veris® map at Coonalpyn showing a soil pH range from 4.1 to 8.2 ($CaCl_2$).

Figure 8: Showing the NDVI map for beans. Where the soil pH is low – beans are not growing so well (red areas). Dark blue is good growth (Source: Data Farming) August 2020.

Yield penalty

When the soil pH falls below 5.5 ($CaCl_2$) then the yield of crop and pastures starts to decline. Table 3 and 4 show the estimated yield penalty for various crops and pastures with increasing soil acidity.

The data has been sourced from research trials, observations and pH vs yield maps.

Table 3: Estimated yield penalty for various crops with increasing soil acidity

Crop type	Production losses (tonnes per hectare)		
	Soil pH ($CaCl_2$) 5.5 - 5.0	**4.9 – 4.51**	**≤4.5**
Wheat (Tolerant)	0	0.2	0.4
Barley	0.2	0.6	1.0
Peas	0.2	0.4	1.0
Lupins	0	0.2	0.4
Beans	0.2	0.6	1.2
Lentils	0.2	0.6	1.2
Hay	0.2	0.4	0.8
Canola	0.2	0.6	1.0
Other (oats / triticale)	0	0.2	0.4

Table 4: Estimated yield penalty for pastures with increasing soil acidity

Crop type	Production losses (tonnes per hectare)		
	Soil pH ($CaCl_2$) 5.5 - 5.0	**4.9 – 4.51**	**≤4.5**
Acid sensitive (medic)	0.2	0.6	1.0 – 1.2
Acid tolerant (sub-clover)	0	0.2	0.4

Taking the area from each of the acidic ranges from the soil pH map (Figure 7) and multiplying this by the production losses (Table 3 or 4) and the current commodity price ($/t) will provide an estimate of income lost, which can be quite substantial.

Treatment

Acid soils can be treated either with lime or with mechanical soil modifications provided that the underlying clay has a neutral or alkaline pH.

Lime

Lime is used to neutralise soil acidification (Figure 9). The amount of lime required to treat acid soils depends on the initial soil pH, the target soil pH, soil texture and lime quality.

Soil texture and liming rate

To raise the soil pH by **1 pH unit** requires:

2 t/ha of lime for sandy soils; 3 t/ha of lime for sandy loams or 4 t/ha for loam to clay loam soils.

Reduce rates by 25% if organic matter is low. Do not raise the soil pH by more than one unit at any one time as this may induce a trace element deficiency of manganese or zinc.

For example, if the current soil pH is 4.5 for a sandy soil then 2 tonnes of lime per hectare should raise the soil pH to a targeted level of pH 5.5 ($CaCl_2$). The lime requirement is based on pure lime or a Neutralising Value (NV) of 100%.

If the material is less than this then higher rates of lime can be used. For example, if you need to use 2 t/ha and the lime has a NV of 80% then 100/80 x 2 then 2.5 t/ha can be used.

Figure 9: Applying lime

The cost of lime per hectare depends on the lime quality (NV and particle size), freight costs, distance travelled from the lime source to the paddock and the application costs.

In the Coorong – Tatiara District Council area lime can be obtained from a number of sources.

Example of calculating lime rate

Assuming that a paddock with a sandy soil at Coonalpyn had a soil pH of 4.5 ($CaCl_2$) then the cost of the lime from the above sources to raise the soil pH to 5.5 ($CaCl_2$) taking into account the lime quality, freight, distance and spreading costs would vary from $125 to $184/ha.

As lime does not move quickly through the soil, mixing lime within the top-soil with tillage will improve its effectiveness. Lime may take up to two to five years to be fully effective.

Once the top-soil pH has been raised to pH 5.5 ($CaCl_2$) and assuming a rotation of wheat, barley, beans the pay-back period would be in the order 1 to 1.5 years. A maintenance rate of approximately 1 – 2 t/ha tonnes would be required about every 10 years.

A decision support tool for calculating lime application rates for acid soils and comparing the cost of lime from different lime suppliers for your paddock taking into account the cost of lime, lime quality, freight and distance has been developed by PIRSA. This is available from the web-site: https://acidsoilssa.com.au/.

Soil Modification

There can be a range and a combination of machinery to modify soils to improve the soil pH both with and without lime. Ripping, delving or clay spreading are options for the treatment of acid soils by mixing neutral or alkaline clay through the top-soil. The pH of the sub-soil clay should be checked before using these methods.

Table 5 summarises some of the soil modification treatments, the estimated costs and the estimated pay-back periods. The pay-back period has been based on a wheat, barley, beans, wheat, barley, pasture rotation once the desired pH has been achieved.

The pay-back period has focused primarily on treating acid soils but there are other benefits such as overcoming water repellent sands, reducing compaction, reducing erosion, improving soil structure and fertility and improving water holding capacity.

Table 5: **Soil modification treatments for acid soils, approximate costs and pay-back periods**

Tillage method	Summary	Approx. cost ($/ha)	Approx. payback period (years)	Estimated time the treatment may last (years)
Deep Ripping	Deep Ripping results in minimal incorporation depending on the ripper tynes, however it can bring up some neutral to alkaline clay that can influence surface soil acidity provided that the clay is within 0.6 metres of the surface.	60 - 100	0.6 – 1.0	2-10
Spading	Mixes soil to a maximum working depth of 0.35 -0.4 metres. Can incorporate a range of surface spread amendments (e.g. lime, gypsum, organic matter, sub-soil clay and nutrients).	130	1.2	3-10
Delving and Incorporation	Delving is the use of wide tynes and bringing up neutral to alkaline clay from the lower part of the soil profile to the surface provided that the clay is within 0.6 metres of the surface. Once the clay is brought to the surface it requires incorporation into the surface soil (Figure 10).	300-450	1.9 – 2.3	10+
Clay Spreading and Incorporation	If the clay is too deep in the profile for ripping or delving then clay spreading can be an option. Clay spreading is the removal of sub-soil clay from excavated soil pits, transporting it to the site and spreading it on the soil surface (Figure 11). The total distance from the clay pit must be considered in the total cost per hectare. If the distance is too far, the cost of transporting the clay to the site will prove un-economic. Clay spreading rates can vary from 150 to 250 t/ha with most farmers in the SE now using the higher rates, particularly in the higher rainfall areas. The neutral or alkaline clay on the surface will need to be fully incorporated. The total cost depends on the machinery used, amount of clay applied per hectare, distance from the pits, the amount of over burden of material stockpiled, and incorporation.	500-800	2.5 – 4.0	Up to 20+

Other machinery can include deep ripping with inclusion plates, off-set discs, one-way plough, mouldboard plough etc.

A recent innovation is the Bednar Terraland Ripper machine that is a combination of deep ripping and spading. This is more suited to the shallow sand over clay soils.

Other treatments that can improve soil pH include biochar, composts and manures but these are generally only used on small areas.

If alkaline irrigation water is used, then this can also have an alkalising effect.

Figure 10: Delving

Figure 11: Clay Spreading (Credit: Graham Gates)

Summary

Soil acidity is becoming an emerging and significant problem throughout the Coorong and Tatiara District Council areas especially on the sandy to sandy loam textured soils and is having a detrimental effect on crop and pasture yields.

Both surface and sub-surface soils should be monitored on a regular basis, at about every five years to determine the soil pH.

Soil acidity can be prevented and treated through liming and / or soil modification methods.

References

Price G. (2006) *Australian Soil Fertility Manual* (Third Edition), Australian Fertiliser Federation and CSIRO.

Further information

Further information can be obtained from the web-site at: https://acidsoilssa.com.au/

Australian Government | National Landcare Program | Coorong District Council | Tatiara the good country | Coorong Tatiara Local Action Plan | Government of South Australia Department of Primary Industries and Regions

This project is supported by the Coorong and Tatiara District Councils, through funding from the Australian Government's National Landcare Program.

This event has been supported by several funding bodies that appreciate your feedback.

Please complete the survey below either by;

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1. Can you please rate this event?
5 stars being , 1 star being very average.

Very Average — OK — Outstanding

☆ ☆ ☆ ☆ ☆

2. Has today's event/session increased your knowledge of soil carbon?

- ◯ Yes
- ◯ No
- ◯ Some increase in knowledge

3. As a result of the information you have received today, are you likely to follow-up on any of the matters covered, or make any business or on-ground changes?

- ◯ Yes
- ◯ Maybe
- ◯ No

https://www.surveymonkey.com/r/FC3Y59J