Soil Acidity and Treatment in the Coorong and Tatiara District Council areas

Prepared for the
Coorong and Tatiara Local Action Planning Committees

Andrew Harding and Brian Hughes

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Disclaimer

All Enquiries

Department of Primary Industries and Regions
Mr Andrew Harding, Senior Consultant

PIRSA Research Centre
70 Farrell Flat Road
CLARE SA 5453
T 08 8842 6231 M 0417 886 835
E andrew.harding@sa.gov.au

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Executive Summary

The Coorong and Tatiara District Council's covers a combined area of 1.54 million hectares. This is a productive agricultural area with a total value of annual agricultural production of $490 million that is approximately 7.9% of the State's agricultural output (ABS, 2015-16).

Dryland pastures are grown for grazing, hay and seed production. Crops grown throughout the area are mainly cereals (wheat, barley, oats) with pulses (beans, lupins, peas, lentils) and oilseeds (canola). A small area is irrigated for lucerne seed production as well as wine-grapes, potatoes, onions, other vegetables, olives, pasture and grass seeds.

The main soil groups that cover nearly 80% of the area include: shallow soils on calcrete or limestone; sand over clays; and deep sands. Other soil groups include: wet (saline) soils; deep loamy texture contrast soils with dark brown or dark sub-soil; cracking clays; and calcareous soils.

Due to more productive and intensive farming practices soil acidity is becoming an emerging and significant problem throughout the area, particularly on the sandy and sandy loam soils.

When the soil pH falls below pH 5.5 ($CaCl_2$) then productivity of crops and pastures starts to fall, nutrients such as phosphorus, magnesium, calcium and molybdenum become less available to the plants; microbial activity begins to decline (including *Rhizobia*) and toxic levels of aluminium start to become a problem that can severely impair root and plant growth.

The area currently acidic or likely to become acidic in the next 5 - 10 years is approximately 334,515 hectares or 35.9% of the agricultural area with an estimated annual production loss of $5.8 million.

It is estimated that a further 375,114 hectares of agricultural land has the potential to become acidic in the next few decades assuming that that current farming practices continue, and that soils are not adequately treated by liming or other soil modifications, a further annual production loss of $6.1 million is anticipated.

Lime and / or soil modification techniques such a ripping, spading, delving or clay spreading are options for the treatment of acid soils provided that the underlying clay is neutral to alkaline. Other treatments that can improve soil pH include biochar, composts and manures but these are generally only used on small areas. The application of alkaline irrigation water can also have an alkalising effect.

The payback periods were based on a rotation of wheat, barley, beans, wheat, barley, pasture. From this it was determined that the payback period for liming is about 1 to 1.5 years while the payback period for ripping is 0.6-1.0 years; spading 1.2 years; delving and incorporation 1.9 – 2.3 years; and clay spreading and incorporation 2.5 – 4.0 years.

1. Introduction

The Coorong and Tatiara District Councils cover an area of 1.54 million hectares. This is a productive agriculture area with a total value of annual agricultural production of $490 million that is approximately 7.9% of the State's agricultural output (ABS, 2015-16).

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This report has been prepared for the Coorong and Tatiara District Councils and the Coorong and Tatiara Local Action Planning Committees to:

- Investigate the extent and severity acid soils throughout the area;
- Determine crop and pasture yield penalty due to acid soils and;
- Review the treatment options and costs to ameliorate acid soils and determine pay back periods.

2. General Description of the Coorong and Tatiara District

The Coorong District Council covers an area of 886,084 hectares and the Tatiara District Council covers an area of 652,097 hectares comprising a total area of 1.54 million hectares.

2.1 Climate

The area has a temperate climate with cool wet winters and warm to hot dry summers. The average annual rainfall ranges from about 360 mm (Sherlock) to about 517 mm (Padthaway) (Figure 1). The rainfall averages for various centres are outlined in Table 1. Most of the rain falls between April and October comprising about 70 -75% of the annual total. Intense thunderstorms can occur in spring and summer.

In wet winters, flooding and waterlogging can occur in poorly drained low-lying areas.

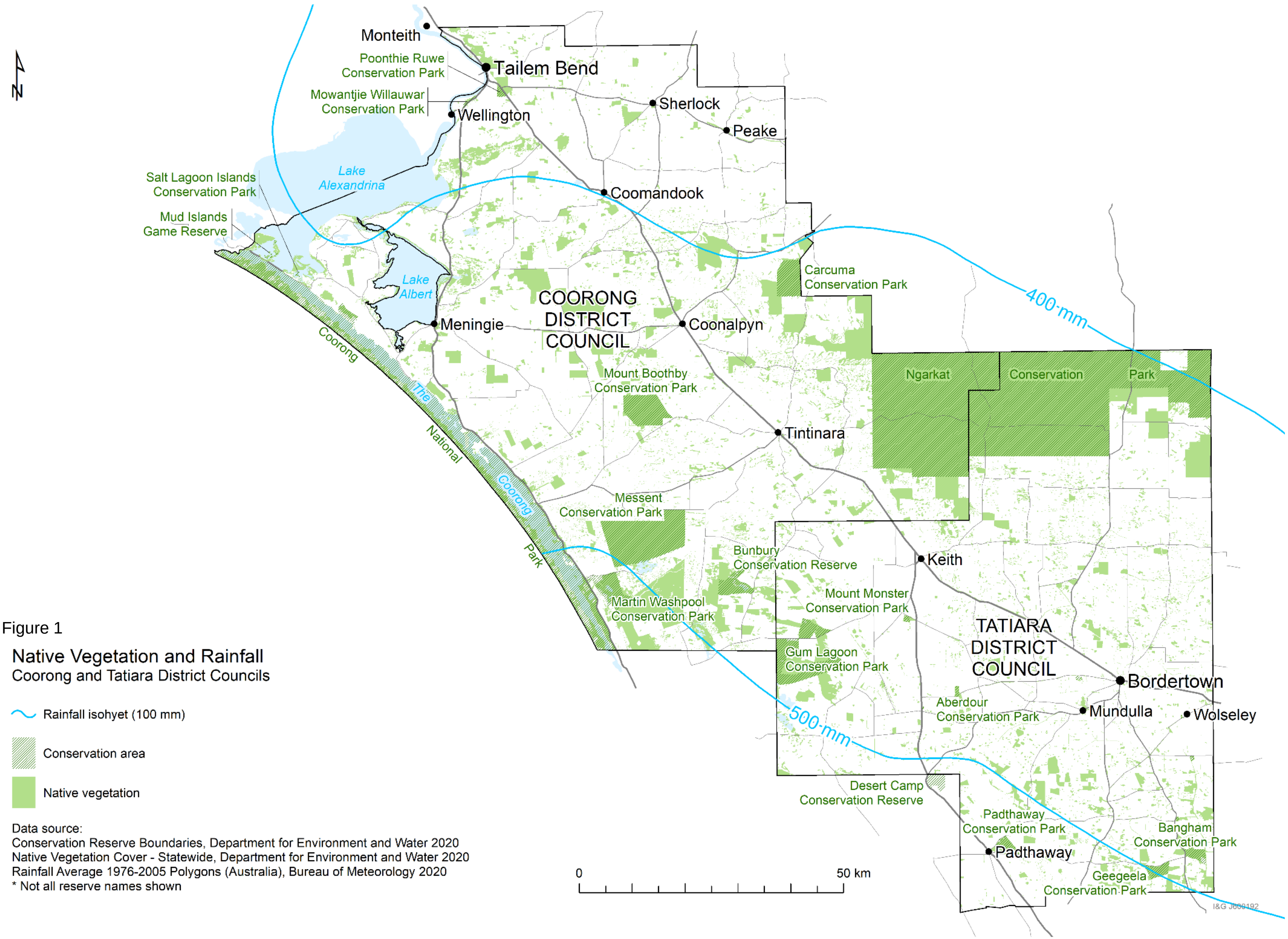


Figure 1

Native Vegetation and Rainfall
Coorong and Tatiara District Councils

Data source:
Conservation Reserve Boundaries, Department for Environment and Water 2020
Native Vegetation Cover - Statewide, Department for Environment and Water 2020
Rainfall Average 1976-2005 Polygons (Australia), Bureau of Meteorology 2020
* Not all reserve names shown

Table 1: Average annual rainfall for centres (year commenced in brackets)

Centre	Average annual rainfall (mm)	Centre	Average annual rainfall (mm)
Bordertown	435 (2002)	Meningie	468 (1864)
Coomandook	414 (1901)	Padthaway	517 (1935)
Coonalpyn	451 (1887)	Tailem Bend	371 (1907)
Keith	459 (1906)	Tintinara	465 (1900)

Reference: Bureau of Meteorology

The average annual evaporation in the Coorong District Council area ranges from 1,500 mm in the south to around 1,800 mm in the north (Coorong District Local Action Planning Committee, 2012).

2.2 Topography

The Coorong District Council area is largely a low-lying coastal plain with a succession of old calcareous coastal dunes and interdunal flats, with low sandhills and sandplains being common. The dunes generally trend north-west to south-east, parallel to the coastline. They are usually 10-30 metres above sea level to a maximum height of 170 metres above sea-level between Meningie and Coonalpyn.

In the Tatiara District Council area there are two distinct landforms, the sand dune and clay highlands (Mallee highlands) to the north-east and the remnant coastal plain to the south-west (coastal plain).

On the coastal plains the ridges and interdunal flats are generally aligned in a north-west to south-east direction and surface drainage on the flats is generally to the west and northwest.

2.3 Soil types

Within the Coorong and Tatiara District Council area there are 11 soil groups (Figure 2). These are described in Appendix 1 and can be further sub-divided according to different soil characteristics as outlined in Appendix II.

Table 2: Main soil groups in the Coorong and Tatiara District Council area

Soil group	Area (hectares)			Percent of total area
	Coorong DC	Tatiara DC	Total	
Shallow soils on calcrete or limestone	322,771	120,930	443,701	28.8
Sand over clay soils	180,162	212,364	392,526	25.5
Deep sands	223,127	157,810	380,937	24.8
Wet soils	42,785	28,362	71,147	4.6
Deep loamy texture contrast soils with dark brown or dark sub-soil	3,315	54,296	57,611	3.7
Cracking clay soils	6,747	44,971	51,718	3.4
Calcareous soils	35,608	1,247	36,855	2.4

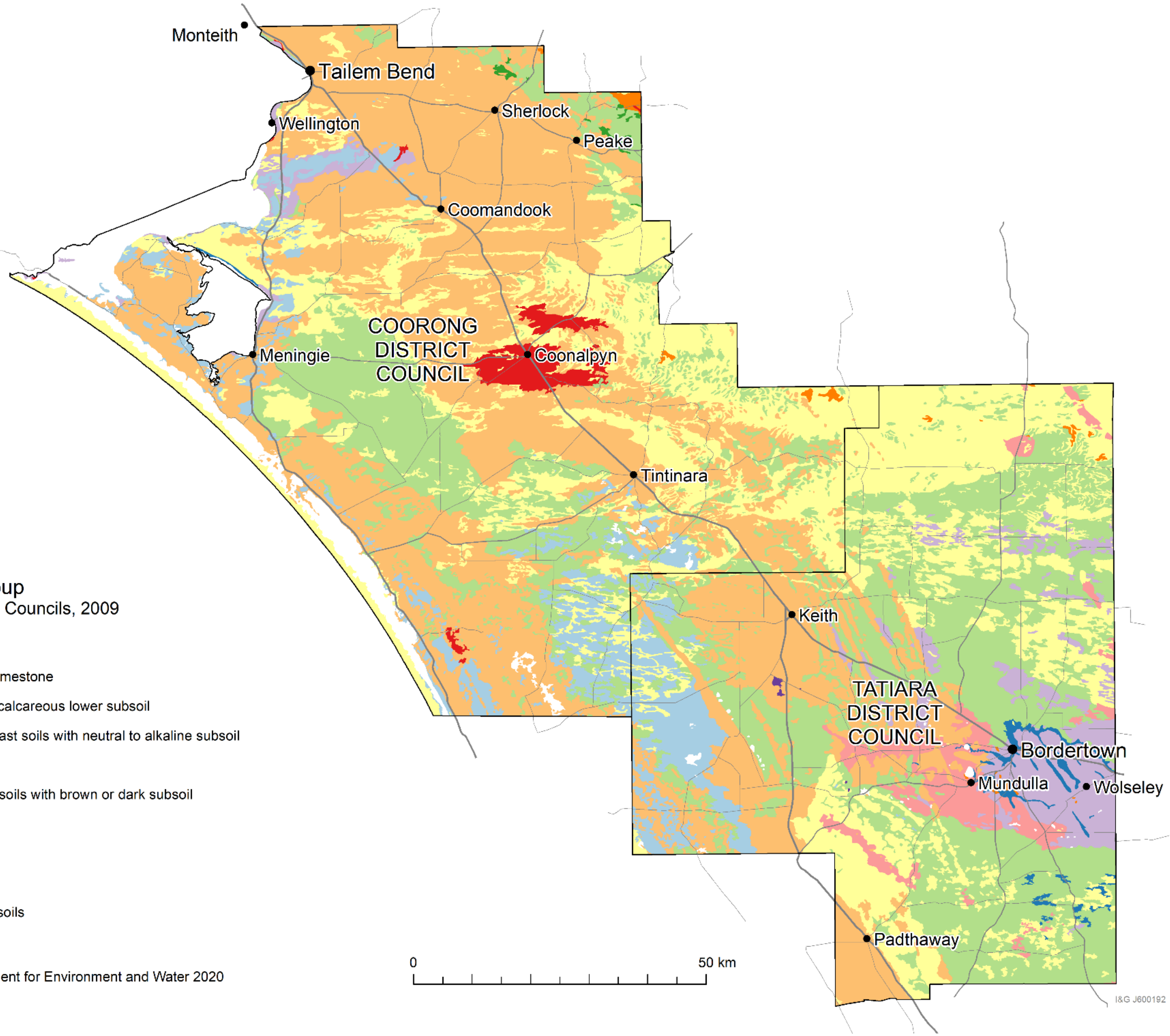


Figure 2

Most Common Soil Group

Coorong and Tatiara District Councils, 2009

- Calcareous soils
- Shallow soils on calcrete or limestone
- Gradational soils with highly calcareous lower subsoil
- Hard red-brown texture contrast soils with neutral to alkaline subsoil
- Cracking clay soils
- Deep loamy texture contrast soils with brown or dark subsoil
- Sand over clay soils
- Deep sands
- Shallow soils on rock
- Deep uniform to gradational soils
- Wet soils

Data source: Soil Groups, Department for Environment and Water 2020

Hard red-brown texture contrast soils with neutral to alkaline sub-soil	5,093	18,392	23,485	1.5
Deep uniform to gradational soils	1,164	7,646	8,810	0.6
Gradational soils with highly calcareous lower sub-soil	5,560	0	5,560	0.4
Shallow soil on rock	12	333	345	0
Not applicable (water, rock, un-mapped)	59,740	5,746	65,486	4.3
Total area	**886,084**	**652,097**	**1,538,181**	**100**

The major soil groups in the area are: shallow soils on calcrete or limestone; sand over clay; and deep sands. Other groups are: the wet soils (saline); deep loamy textured contrast soils; cracking clay loams; and calcareous soils. Minor groups include: hard red-brown earth texture contrast soils; deep uniform to gradational soils; gradational soils with highly calcareous lower sub-soil; and shallow soil on rock.

2.4 Land use

Dryland pastures are grown for grazing with sheep and cattle, hay and seed production. Crops grown throughout the area are mainly cereals (wheat, barley, oats) with pulses (beans, lupins, peas, lentils) and oilseeds (canola). A small area is irrigated for lucerne seed production as well as wine-grapes, potatoes, onions, other vegetables, olives, pasture and grass seeds. Figure 3 shows the areas of different landuse. Dairying is a significant industry in the Narrung / Meningie area.

The Coorong and Tatiara District Council area contains a reasonably large amount of native vegetation (20.3%). This is mostly in Conservation Parks and Heritage Agreement areas.

Table 3: Native vegetation in the Coorong and Tatiara District Council area

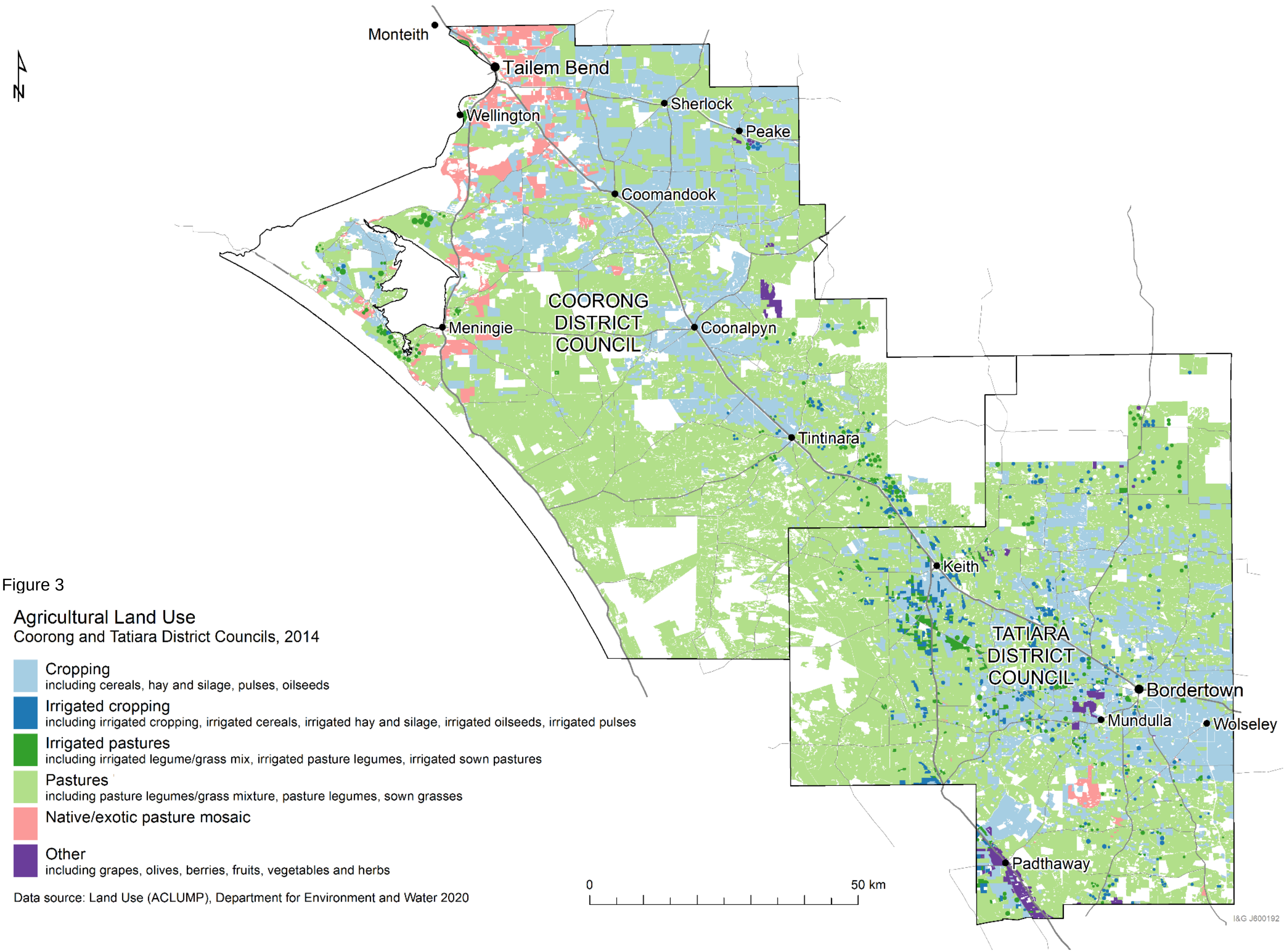
	Total area (ha)	Area covered by native vegetation	Percent covered by native vegetation
Coorong District Council	886,084	184,255	20.8
Tatiara District Council	652,097	128,377	19.7
Total (land)	**1,538,181**	**312,632**	**20.3**

The largest conservation parks are Ngarkat and Messent Conservation Park and the Coorong National Park (Figure 1).

Figure 3

Agricultural Land Use

Coorong and Tatiara District Councils, 2014



Data source: Land Use (ACLUMP), Department for Environment and Water 2020

3 Soil Acidity

3.1 Cause and effect

Soil acidity is becoming an emerging and significant problem throughout the Coorong and Tatiara District Council area especially on the sandy to sandy loam textured soils.

Soil acidification is a natural process, but it is accelerated by intensive and productive farming practices. It 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 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 this has expanded the areas where soils were not previously affected.

Ammonium based nitrogen fertilisers 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 the soil pH falls below 5.5 ($CaCl_2$) nutrients such as phosphorus, magnesium, calcium and molybdenum become less available.

Soil acidity can also reduce microbial activity including *Rhizobia* which are important for the nodulation of legumes. As the pH falls, toxic amount of aluminium can be release 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 associated with a financial loss particularly for acid-sensitive plants.

Lucerne, lentils, annual medics and Faba beans are all sensitive to acid soils. As the soils become more acidic then less sensitive crops may start to become affected. Table 4 shows the tolerance of crops and pastures to low soil pH.

Table 4: 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 un-even crop and pasture growth, yellowing of crops, poor nodulation of legumes and stunted root growth (Figure 4). If soil acidification is allowed to continue, further decreases in productivity are likely, limiting plant options to only acid tolerant crops and pastures.

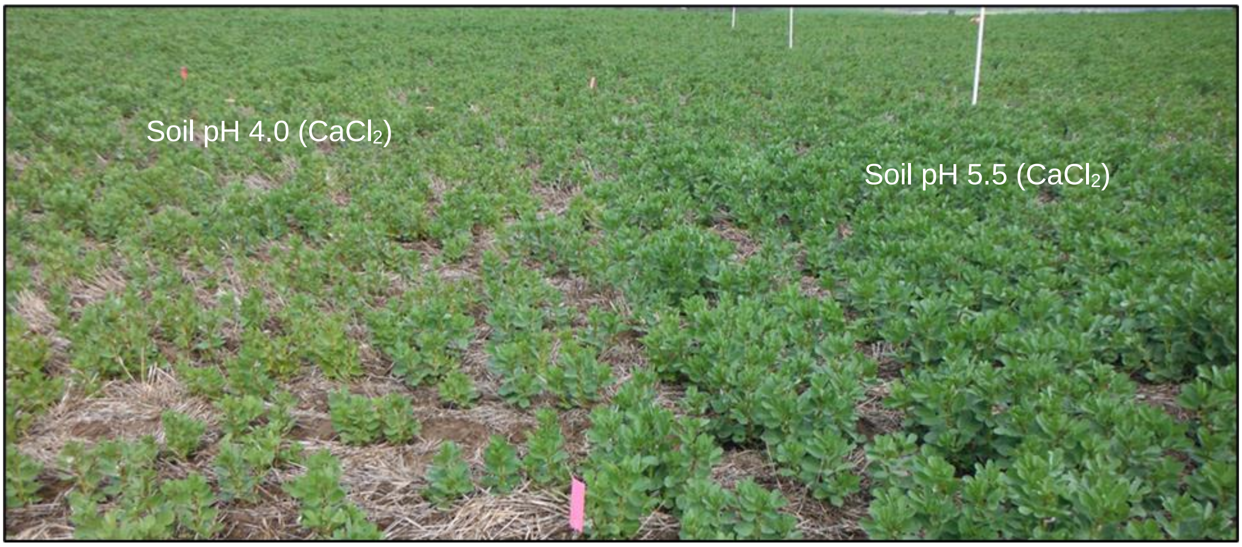


Figure 4: Symptoms of low soil pH (soil acidity) on a Faba bean crop.

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

If soil acidification continues then then the 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 a 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.

The development of soil acidity in susceptible areas of the Coorong and Tatiara area previously un-affected has been recognised for some time. Productive farming practices will continue to acidify these areas and the extent and severity of acidic soil will increase unless adequate on-going treatment such as liming or soil modification (provided that neutral or alkaline clay is available) is implemented.

3.2 Land resource summary

Figure 5 shows the area of the Coorong and Tatiara area that is prone to acid soils. It shows the area of surface soil (0-10 cm) that are currently acidic i.e. pH less or equal to 5.5 ($CaCl_2$) (or prone to acidification in the short term) and soils that are not currently recognised as acid prone but could be become acidic over the next few decades without treatment.

The area currently acidic or likely to become acidic in the next 5-10 years is approximately 334,515. hectares or 35.9% of the cleared area. This is mostly south-east of Meningie and north and south of Bordertown on the sand over clay soils and deep sands.

It is estimated that a further 375,114 hectares of cleared land has the potential to become acidic in the next few decades assuming that current farming practices continue and if these soils are not adequately treated by liming. There are already many paddocks in these areas showing up as having acidic soils.

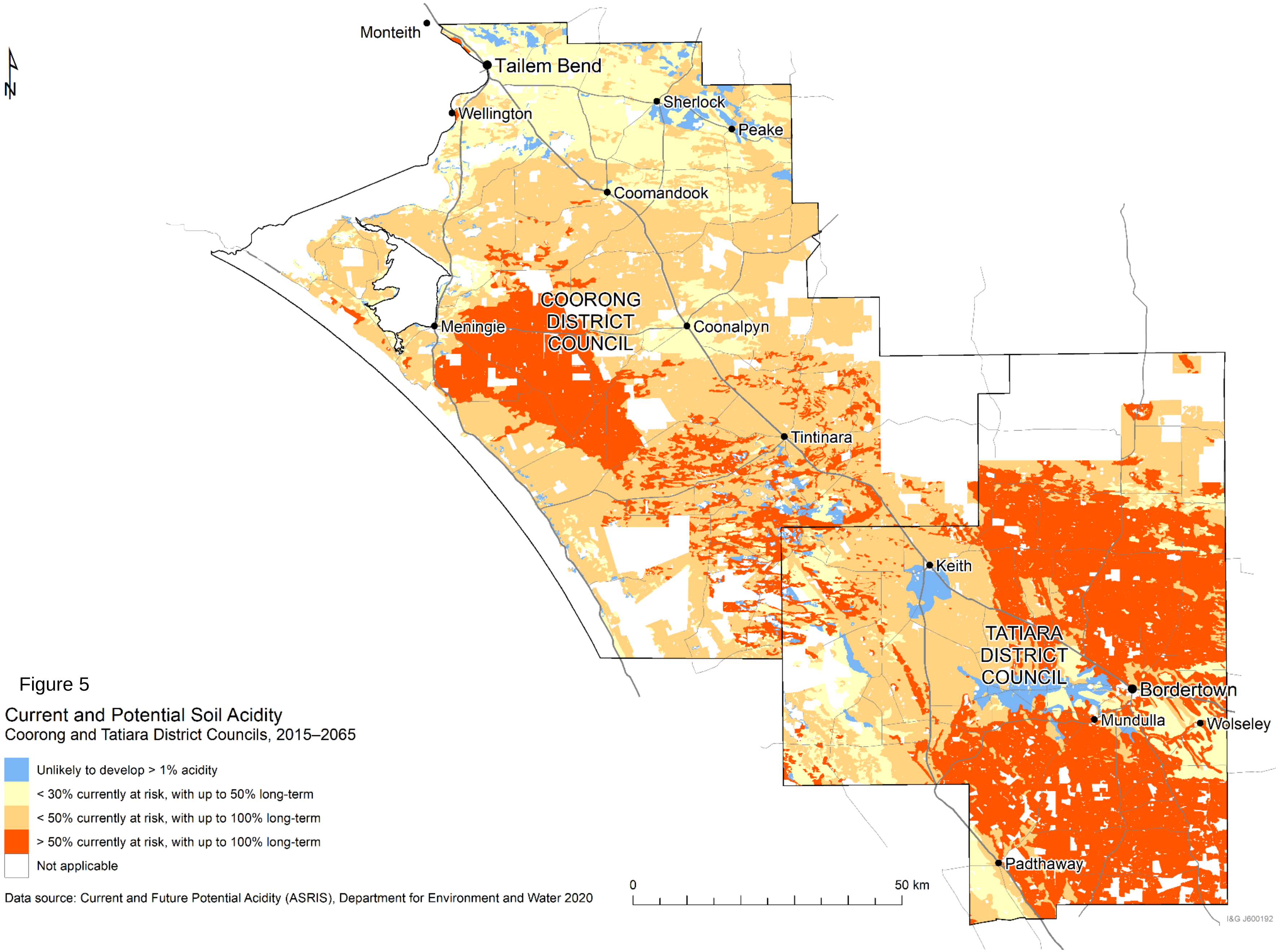


Figure 5

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

Highly productive, intensive cropping systems with high nitrogen inputs and highly productive legume pastures cause the highest rates so this land is most at risk of soil acidification, even though the soil pH may be close to neutral. Soil acidification will occur more quickly on the low buffering soils (i.e. sandy textured soils). Emerging soil acidity can appear in a patchy formation within paddocks depending on the soil type and management practices (Figure 4 & 9).

Soils with a surface pH of at least 7.5 ($CaCl_2$) or that are highly calcareous in nature are considered to have no future acidification potential.

The current and future potential of acid soils in the agricultural areas (cleared land) is shown in Table 5.

Table 5: Current and future potential of acid soils in the cleared areas.

Category	Coorong DC (ha)	Tatiara DC (ha)	Total (ha)
Currently acidic (next 5 - 10 years)	117,825	216,690	334,515
Not currently acidic but prone to acidification in the next 10 - 50 years	255,448	119,666	375,114
Not susceptible to acidification	123,825	98,568	222,393
Not applicable (includes water, rock etc.)	4,538	1,031	5,569
Total	**501,636**	**435,955**	**937,591**

3.3 Soil pH test data

All soil pH test data including surveillance and monitoring sites, soil test data and soil pH mapping were compiled throughout the area to have a better understanding of the extent and severity of acid soils.

3.3.1 Surveillance and monitoring sites.

As part of a number of projects including the Australian Government ‘Caring for our Country’ and DEWNR project ‘Taking Action on Acid Soils’ during 2008 - 2011 a number of surveillance and long-term monitoring sites were established, mostly in acid prone areas (Forward and Hughes, 2019).

Surveillance sites are designed for rapid surface measurements of pH whereas monitoring sites are selected as long-term sites where soil pH changes are measured at set depths (generally at 10 cm increments) down the profile and over time.

Throughout the Tatiara District Council area there were 29 surveillance sites (mostly north and south of Bordertown) and 10 long term monitoring sites.

Of the surveillance sites in the Tatiara District Council area the average soil pH ($CaCl_2$) for surface soil (0-10 cm) was 5.6. Sixty two percent had a soil pH less than or equal to pH 5.5 ($CaCl_2$) while 28% of the sites had a pH less than or equal to pH 5.0 ($CaCl_2$). The lowest sample was pH 4.4 ($CaCl_2$) and the highest reading was 7.5 ($CaCl_2$).

In the 10-20 cm layer the average soil pH ($CaCl_2$) from 27 samples was 5.7. Thirty seven percent had a soil pH less than or equal to 5.5 ($CaCl_2$) while 22% had a pH less than or equal to 5.0 ($CaCl_2$), highlighting the extent of sub-surface acidity. The lowest sample was pH 4.3 ($CaCl_2$) and the highest reading was 8.0 ($CaCl_2$).

In terms of the long-term monitoring sites, that were located in high production cropping systems, six (60%) of these have a soil surface (0-10 cm) pH less than or equal to pH 5.5 ($CaCl_2$) and 5 (50%) of these sites have a sub-surface (10-20 cm) pH of less than or equal to pH 5.0 ($CaCl_2$). In some of the sites where alkaline / calcareous clay has been applied this has improved the soil pH on the surface but acidification has continued below 10 cm (Hughes *et. al.* 2017).

A small soil acidity project in the District Council of Tatiara has shown from soil testing that some cropped or grazed paddocks with sandy and deep sandy soils that were previously delved or clay spread with alkaline / calcareous clay approximately 10 to 20 years ago have re-acidified (Dennerley and Fraser, 2016).

There are no surveillance sites or monitoring sites in the Coorong District Council area.

3.3.2 Soil test data

Every effort was made to source landholder soil data. In the Tatiara District Council 201 landholder soil tests (0-10 cm) were received. These soil tests covered a range of soil types and land use including dryland cropping, dryland pastures, lucerne, onions and vineyards. The average soil pH ($CaCl_2$) was 6.3.

Twenty five percent had a soil pH less than or equal to pH 5.5 ($CaCl_2$) while 10% of the sites had a pH less than or equal to pH 5.0 ($CaCl_2$). The lowest sample was pH 4.5 ($CaCl_2$) and the highest reading was 8.3 ($CaCl_2$).

In the Coorong District Council area only 16 soil tests were received (eight at 0-10 cm and eight at 10-20 cm). All of the test results were below pH 5.7 ($CaCl_2$). The average soil test (0-10 cm) was pH 4.9 ($CaCl_2$) and the lowest was pH 4.1 ($CaCl_2$). The average sub-surface soil test (10- 20 cm) was pH 5.1 ($CaCl_2$) and the lowest was pH 4.1 ($CaCl_2$).

3.3.3 Soil pH mapping information

Soil pH mapping has been available to landholders since 2015 either through grid mapping or with a Veris® soil pH mapping machine (Figure 6). It has been estimated that a total of about 30,000^{+} hectares (approximately 3.2% of cleared areas) has been mapped since 2017 throughout the Coorong and Tatiara District Council's area.

Figure 6: Veris® soil pH mapping machine

Every effort was made to source the soil pH data. Figures 7 and 8 show the information received for each Council area and the breakdown of soil pH levels. Most of the soil pH mapping has been carried out in the Coorong DC area.

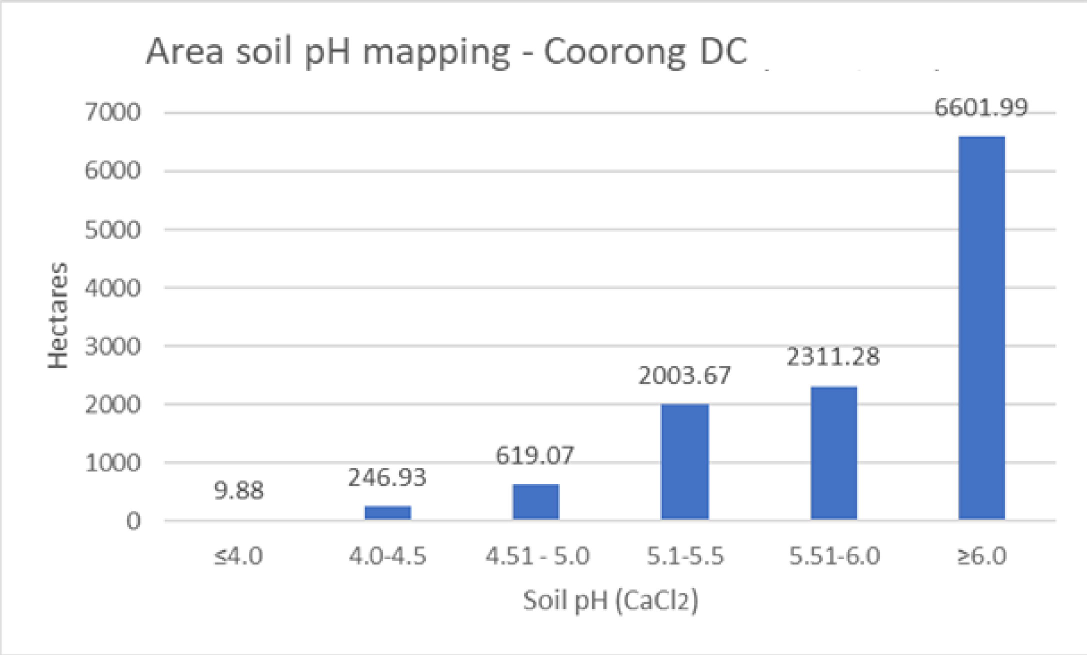


Figure 7: Area soil pH mapping in the Coorong DC area (Total area = 11,793 hectares).

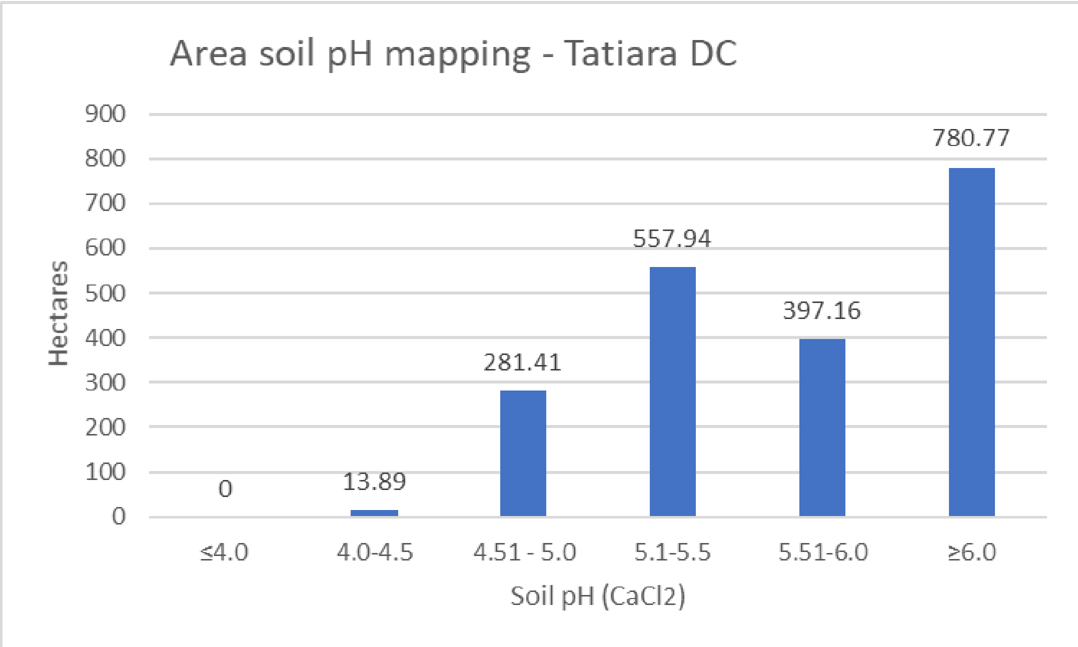


Figure 8: Area soil pH mapping in the Tatiara DC area (Total area = 2,031 hectares).

In the Coorong DC area, 24% of the area (2,880 hectares) mapped had a soil pH less than or equal to pH 5.5 ($CaCl_2$) while 7% of the area (876 hectares) had a soil pH equal to or less than 5.0 ($CaCl_2$).

In the Tatiara DC area, 42% of the area (853 hectares) mapped had a soil pH less than or equal to pH 5.5 ($CaCl_2$) while 14% of the area (295 hectares) had a soil pH equal to or less than 5.0 ($CaCl_2$).

Of the total area mapped (13,824 hectares), 27% (3,733 hectares) had a soil pH less than or equal to pH 5.5 ($CaCl_2$) while 8% of the area (1,171 hectares) had a soil pH equal to or less than 5.0 ($CaCl_2$).

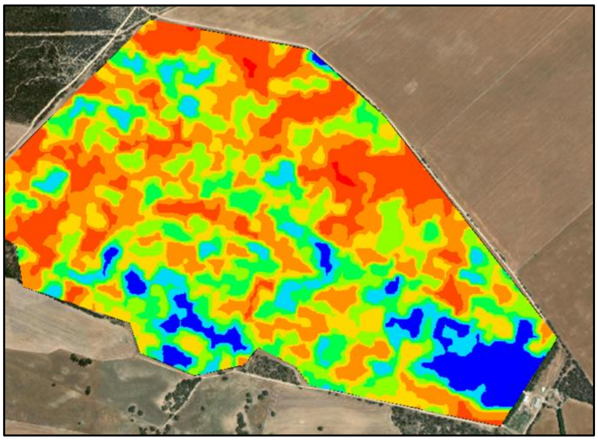
Figure 9 shows an example of a paddock (189.4 hectares) mapped by a Veris® machine. This paddock is west of Coonalypn on a shallow sand over clay with parts of the paddock having a heavier textured top-soil and grading to a calcareous loam.

The map shows the patchiness of soil pH across the paddock. The soil pH ($CaCl_2$) ranges from 4.1 to 8.2 with 70 hectares (37%) having a soil pH ($CaCl_2$) less than 5.5.

Precision soil pH mapping identifies areas for lime to be targeted in the right areas and at the right rates.

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 identifying acid soils. If the maps are showing low NDVI or low yield and if other issues such as disease, nutritional problems, weeds, soil types and other constraints (shallow soils, rockiness etc.) are eliminated then soil pH may be the underlying cause.

Figure 9 and 10 shows the correlation between the soil pH map and NDVI map (for beans). Where the soil pH is low the beans are not growing as well.



pH	Area
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 9

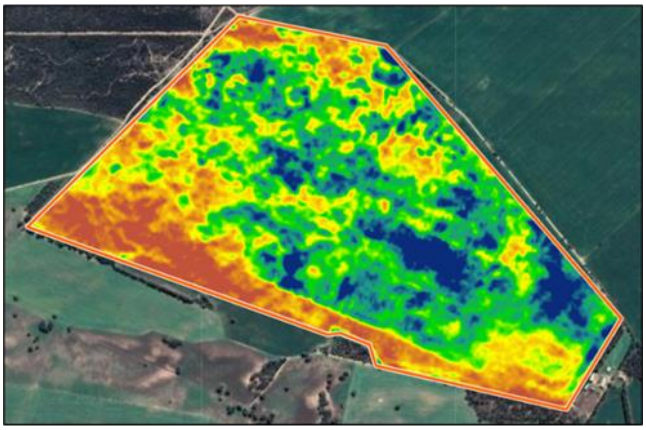


Figure 10

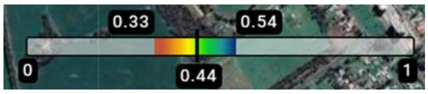


Figure 9: Soil pH Veris® map at Coonalpyn showing a soil pH range from 4.1 to 8.2 ($CaCl_2$).

Figure 10 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.

From the paddock (189 hectares) shown in Figures 9 & 10 the value of production loss for beans would be in the order of $10,000 (Table 8) or an average loss of $53/hectare.

3.4 Yield penalty

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

Table 6 and 7 shows the estimated yield penalty for various crops and pastures with increasing acidity. This data has been sourced from research trials, observations and pH vs yield maps.

Table 6: Estimated yield penalty for various crops with increasing soil acidity.

Crop type	Production losses (t/ha)		
	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 7: Estimated yield penalty for pastures with increasing soil acidity.

Crop type	Production losses (t/ha)		
	Soil pH ($CaCl_2$) 5.5 - 5.0	4.9 – 4.51	≤4.5
Acid sensitive	0.2	0.6	1.0 – 1.2
Acid tolerant	0	0.2	0.4

Taking the area from each of the acidic ranges from the soil pH map (Figure 9) and multiplying this by the production losses (Table 6 and 7) and the current commodity prices ($/t) (Appendix III) provides an estimate of income lost (Table 8).

Table 8: Value of production losses (based on Figure 9)

	pH 5.5 - 5.0	pH 4.9 – 4.51	pH <4.5	Total ($)
Area (hectares)	42.87	27.03	0.51	
Crop	**Value of production losses per crop per annum ($)**			
Other (oats / triticale)	0	1,243	47	1,290
Wheat (tolerant)	0	1,406	53	1,459
Hay	1,543	1,946	73	3,563
Lupins	0	1,622	61	1,683
Barley	1,886	3,568	112	5,566
Peas	3,258	4,109	194	7,560
Beans	3,430	6,487	245	10,162
Canola	4,716	8,920	281	13,916
Lentils	6,002	11,353	428	17,783
Pasture (acid tolerant)	0	649	24	673
Pasture (acid sensitive)	1,029	1,946	61	3,036

Assuming a wheat, barley, beans, wheat, barley, pasture (acid sensitive) rotation the production loss over six years would be $27,248 or on average $144/hectare.

The annual value of production loss due to acid soils has been calculated for the Coorong and Tatiara District Council areas (Appendix IV & V). For the area that is currently acidic or likely to become acidic in the next 5 – 10 years (not treated) it is estimated that the annual production loss is $5.8 million.

The annual value of production loss that is likely to become acidic in the next few decades is estimated at $6.1 million giving a total production loss of $11.9 million per annum (Appendix V).

3.5 Treatment

Acid soils can be treated either with lime or through ripping, delving, spading and clay spreading, provided that the underlying clay is neutral or alkaline.

3.5.1 Lime

Lime is used to neutralise acid soils. The amount of lime required 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 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 trace element deficiencies such as 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 of lime can be used.

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 including: Henschke Industries Pty Ltd (Naracoorte), Agricola Mining Pty Ltd (Robe), Cawtes Ag lime Pty Ltd (Murray Bridge); Goolwa Quarries Pty Ltd (Murray Bridge); Southern Quarries (Fleurieu Peninsula) or other quarries either north or south.

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 will 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 payback 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 https://acidsoilssa.com.au/

3.5.2 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 throughout the top-soil. The pH of the sub-soil clay should be checked before using these methods.

Table 9 summarises some of the soil modification treatments, the estimated costs and the estimated pay back periods to raise the soil pH from 4.5 to 5.5 ($CaCl_2$). The payback period has been based on a wheat, barley, beans, wheat, barley, pasture rotation once the desired soil pH has been achieved.

The payback period analysis has focused primarily on treating acid soils but there are other benefits derived from ripping, delving and clay spreading and the incorporation of clay such as overcoming water repellent sands, reducing compaction, reducing erosion, improving soil structure and fertility and improving water holding capacity.

For all of the tillage methods outlined below, thorough incorporation of neutral or alkaline pH clay will improve the end results.

Table 9: Soil modification treatments for acid soils, approximate costs and payback periods.

Tillage method	Summary	Approximate cost ($/ha)	Approximate 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 or alkaline clay that can influence surface soil acidity provided that the clay is within 0.6 metres of the surface. Bryce and Pluska (2021) estimate that the effects of deep ripping may last for two to ten years depending on the soil type and traffic management.	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). Bryce and Pluska (2021) estimate that the effects of spading may last three to ten^{+} years.	130	1.2	3-10

Delving and incorporation	Delving (Figure 11) is the use of wide tynes and bringing up neutral to alkaline pH 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.	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 12). 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. The 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 to alkaline clay on the surface will need to be fully incorporated. The cost depends on the machinery used, amount of clay applied per hectare, distance travelled from the pits, the amount of material stockpiled, and the amount of incorporation. Work in the SE has shown that clay spreading has lasted for 40 years with continued improved performance on treated paddocks however, in some paddocks some re-acidification has occurred after 10 - 20 years (Dennerley and Fraser, 2016).	500-800	2.5 – 4.0	Up to 20+

Other machinery options 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 11: Delving

Figure 12: Clay Spreading (credit Graham Gates)

4 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.

Lime and / or soil modification techniques (provided that the underlying clay has a neutral or alkaline pH) such a ripping, spading, delving or clay spreading are options for the treatment of acid soils.

The payback period for liming is about 1 to 1.5 years while the payback period for clay spreading can be in the order of 2.5 to 4.0 years. The payback period will be shorter if more acid sensitive crops are grown throughout the rotation.

5 References

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6 Acknowledgments

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7. Appendices

7.1 Appendix I: Description of soil types in the Coorong and Tatiara area

7.1.1 Shallow soils on calcrete or limestone

The shallow soils on calcrete or limestone comprise 29% of the area and occur from Tailem Bend through Tintinara and Keith towards Mundulla as well as a band along the coast.

The soil profiles are variable but are all underlain by a hard carbonate-rich layer of calcrete, calcrete-capped limestone or calcarenite or occasionally un-capped limestones – at a depth of 50 cm or more (Hall *et. al,* 2009). The calcrete is often fractured and its thickness can vary from a few centimetres to many metres. The hard carbonate layers can act as an impediment to plant root growth and drainage.

The agricultural potential varies across the group but it is largely dependent on the soil depth, texture profile, soil structure, fine carbonate content, rubble content, calcrete thickness and extent of fracturing.

There are nine sub-groups within this group with eight sub-groups occurring in the Coorong-Tatiara District. The groups are differentiated according to the soil surface texture, structure and colour. The most common sub-groups in the area are the: shallow calcareous loam on calcrete (B2); shallow sandy loam on calcrete (B3); shallow loam over red clay on calcrete (B6) and the shallow sand over clay on calcrete (B7).

The inherent fertility of these soils is due to the surface texture. The shallow loam over red clay and calcrete (B6) have a moderate to high fertility due to the clay content and dryland agriculture on these soils is generally moderate to moderately high.

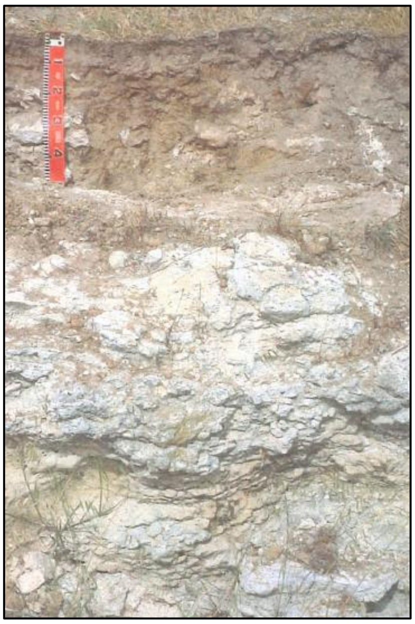

Figure 13: Shallow sand over clay on calcrete near Keith (B7)

The shallow calcareous loam on calcrete (B2) and the shallow sandy loam on calcrete (B3) generally have a moderate to moderately low inherent soil fertility. The soil pH on the shallow sandy loam on calcrete is often slightly acidic to alkaline. Dryland agriculture is moderately low. Wind erosion can be a problem due to overgrazing or excessive cultivation.

The shallow sand over clay on calcrete (B7) is one of the largest sub-group (Figure 13). The top-soils are sandy and have a neutral to acidic soil pH. The inherent soil fertility is moderately low to low as the sandy soils have little capacity to hold nutrients

The dryland agriculture potential on these soils is moderate. Limitations include low soil fertility, potential for leaching from topsoils (especially nitrogen), risk of wind erosion, water repellence, restricted water holding capacity and risk of top-soil acidification.

7.1.2 Sand over clay soils

The sand over clay soils comprise about 25% of the area and occur mainly in a band south-east of Meningie and north and south of Bordertown with smaller areas scattered through the area.

The soil profiles are characterised by a sandy top-soil which is often loose to soft and a distinct colour and texture boundary between the top-soil and the sub-soil. The sub-soil textures are usually clay or clay loam and the sub-soil structure ranges from massive to coarse. The top-soils can be up to one metre thick and often the surface is water repellent. Due to the low permeability of the sub-soils water logging is common.

There are five sub-groups within this group with four of these (G1, G2, G3 and G4) occurring in the Coorong-Tatiara district. The groups are differentiated according to the soil surface texture, structure and depth and the presence or absence of a bleached sub-surface layer. All of the soils except for the G1 soils have a bleached sub-surface layer that is generally 10 to 60 cm thick.

The sandy top-soils have little capacity to retain nutrients and the bleached sub-surface layer has a very poor soil fertility. Organic matter in the surface soil is the major contributor to top-soil fertility.

Adequate phosphorus and nitrogen levels need to be maintained. Nitrogen and sulphur is easily leached in the sandy soils.

Water and wind erosion can be major issues on these soils.

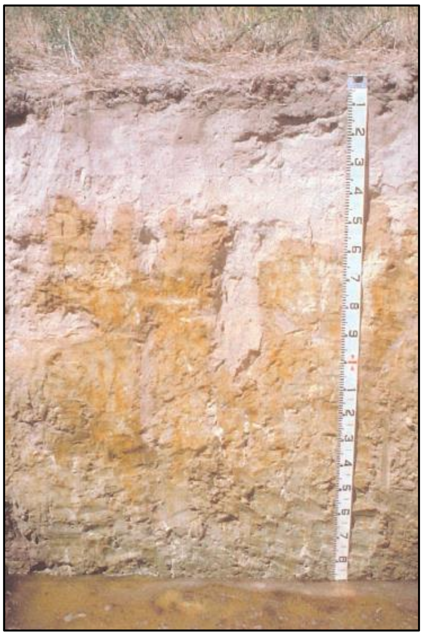

Figure 14: Thick sand over sandy clay west of Tintinara

The soil pH is extremely variable. The top-soils can range from strongly acidic to alkaline and the sub-soils from strongly acidic to strongly alkaline.

Due to product removal and high leaching and low buffering capacity all the top-soils are prone to acidification. More than 50% of these soils are currently at risk of soil acidification with up to 100% in the long term (Figure 5). Sub-soil acidification can also be an issue.

The G1 and G2 soils have a moderate to moderately high potential for dryland agriculture. The G3 soils have a moderate to moderately low potential for dryland agriculture. The G4 soils are the more difficult agricultural soils due to reasonably shallow top-soil and problems with seasonal waterlogging.

7.1.3 Deep sands

The deep sands comprise about 25% of the area. These are deep to moderately deep pale-coloured sandy soils. The soil profiles are sandy throughout. They mostly occur on linear or jumbled inland dunes, coastal dunes, sand spreads and old coastal dune ranges.

There are three sub-groups: carbonate sands (H1); siliceous sands (H2) and bleached siliceous sand (H3). The most common sub-group in the area is the bleached siliceous sands (Appendix II).

All these soils have a low soil fertility, are prone to wind erosion once the surface cover is removed. They are water repellent and prone to soil acidification. A large area of these soils are still covered by native vegetation and are in conservation parks (Figure 1 & 2).

Figure 15: Bleached siliceous sand north-east of Tintinara (H3)

7.1.4 Wet soils

The wet soils comprise about 5% of the area. With these soils, the profiles are saturated for at least two or three months of the year and many are subject to seasonal inundation.

Conditions include a seasonal watertable within one metre of the surface, poor to very poor drainage and a high to extreme watertable-induced salinity.

The productive capacity of these soils is limited. Many off these soils are covered with salt tolerant species e.g. saltbush and samphire and many are within conservation parks.

Figure 16: Wet (saline) soil profile at Tintinara

7.1.5 Deep loamy texture contrast soils with dark brown or dark sub-soil

The deep loamy texture contrast soils with dark brown or dark brown sub-soil comprise about 4% of the area and occur mostly in the Tatiara District Council west and south of Mundulla.

The soil profiles are characterised by a distinct break between the top-soil and sub-soil. The most common top-soil texture is a sandy loam and the sub-soils are clayey. There are two sub-groups within this soil that are differentiated by the top-soil thickness and sub-soil structure. The F1 soils have a loam surface soil often more than 30 cm thick with or without a bleached sub-surface layer over a brown or dark clay while the F2 soils have sandy loam surface soil generally less than 30 cm thick with a bleached sub-surface layer over a poorly structured brown or dark clay.

Seasonal water logging in the form of perched water tables is common due to the low permeability and gentle topography.

The extent to which top-soils can store and release nutrients depends on clay and organic matter content, thickness of any bleached layer and soil pH. The F1 soils have a moderate to high inherent fertility while the F2 soils have a moderate inherent fertility.

The pH on the surface for the F1 soils ranges from acidic to neutral while the sub-soils are acidic to alkaline. The F2 surface soils are generally acidic to alkaline while the sub-soils are neutral to strongly alkaline.

All the top-soils are prone to acidification with the sandier types the most susceptible. Sub-surface and sub-soil soil acidity can be an issue. The dryland agricultural potential for the F1 soils is moderately high and for the F2 soils is moderate.

Figure 17: Loam over a poorly structured brown clay at Mundulla

7.1.6 Cracking clay soils

The cracking clay soils comprise 3% of the area and mostly occur in the Tatiara District Council east of Mundulla.

The soil profiles are uniformly textured and clayey throughout. Due to the high amount of clay these soils swell when wet and shrink and crack upon drying. Large cracks that penetrate from the surface to the sub-soil can be as wide as 10 cm. These soils become sticky when wet affecting the timeliness and efficiency of agricultural operations.

There are two types of these soils that occur in the area. They are E1 black cracking clays and the more common E3 brown or grey cracking clays. All these soils have a very high inherent fertility.

These soils have an acidic to alkaline surface with neutral to alkaline sub-soils that become more alkaline at depth.

Due to their fertility these soils are highly productive however the surface can be difficult to work and patchy germination and un-even plant establishment can occur.

7.1.7 Calcareous soils

The calcareous soils comprise 2% of the area and occur mostly in the Coorong District Council area around Coonalpyn. The soil profiles are calcareous throughout. The surface soil texture ranges from a loamy sand to a clay while the sub-soil texture ranges from sandy loam to heavy clay.

There are eight sub-groups within this group with six sub-groups occurring in the Coorong-Tatiara district. The most dominant sub-group is A4 sub-group (Appendix II). This sub-group has a loamy to clay loamy surface texture over a loamy to light clay sub-soil.

The surface soil has an alkaline surface grading to strongly alkaline at depth. The surface soil contains about 2 to 20% fine carbonate that can limit the availability of some nutrients required by plants. Variable amounts of hard carbonate occur throughout the profile.

Inherent fertility is generally moderately low. The lighter textured profiles are excessively drained, enabling water and soluble nutrients to move beyond the rootzone. The lighter soil types and with low amounts of fine carbonate could be prone to soil acidification if all the natural carbonates have been dissolved. Less than 30% is currently at risk.

The A4 sub-group has a moderately high dryland agricultural potential. The lighter textured soils are prone to wind erosion if they are excessively cultivated or overstocked.

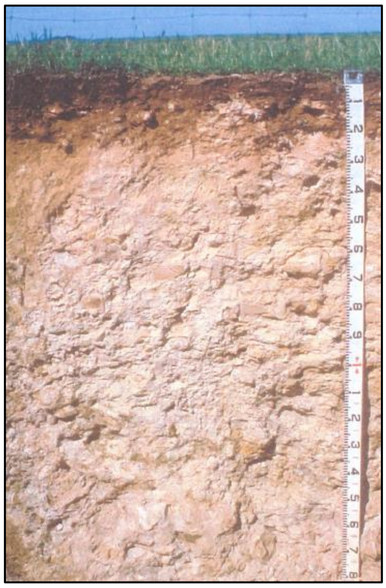

Figure 18: Shallow calcareous sandy loam on calcrete west of Coonalpyn

Other soils that comprise a small area of the Coorong and Tatiara District Council areas, and that have not been described include: hard red-brown textured contrast soils; deep uniform to gradational soils; gradational soils with a highly calcareous lower sub-soil and shallow soil on rock.

7.2 Appendix II: Soil types in the Coorong and Tatiara area by sub-group

Code	Soil Type	Coorong District Council	Tatiara District Council	Total
A	**Calcareous Soil**	**35,608**	**1,247**	**36,855**
A1	Highly calcareous sandy loam	1,319	0	1,319
A4	Calcareous loam	25,748	1,202	26,950
A5	Calcareous loam on clay	5,176	0	5,176
A6	Calcareous gradational clay loam	907	45	952
A7	Calcareous loam on marl	2,183	0	2,183
A8	Gypseous calcareous loam	275	0	275
B	**Shallow soil on calcrete or limestone**	**322,771**	**120,930**	**443,701**
B1	Shallow highly calcareous sandy loam on calcrete	11,613	0	11,613
B2	Shallow calcareous loam on calcrete	51,242	15,039	66,281
B3	Shallow sandy loam on calcrete	118,379	30,841	149,220
B4	Shallow red loam on limestone	0	4,666	4,666
B5	Shallow dark clay loam on limestone	1,288	7,514	8,802
B6	Shallow loam over red clay on calcrete	40,724	9,533	50,257
B7	Shallow sand over clay on calcrete	84,050	42,728	126,778
B8	Shallow sand on calcrete	15,475	10,609	26,084
C	**Gradational soils with highly calcareous lower sub-soil**	**5,560**	**0**	**5,560**
C1	Gradational sandy loam	1,108	0	1,108
C3	Friable gradational clay loam	4,452	0	4,452
D	**Hard red-brown texture contrast soils with neutral to alkaline sub-soil**	**5,093**	**18,392**	**23,485**
D2	Loam over red clay	1,473	2,926	4,399
D3	Loam over poorly structured red clay	3,620	15,413	19,033
D5	Hard loamy sand over red clay	0	53	53
E	**Cracking clay soils**	**6,747**	**44,971**	**51,718**
E1	Black cracking clay	6,394	5,861	12,255

E3	Brown or grey cracking clay	353	39,110	39,463
F	**Deep loamy texture contrast soils with brown or dark sub-soil**	**3,315**	**54,296**	**57,611**
F1	Loam over brown or dark clay	1,833	22,115	23,948
F2	Sandy loam over poorly structured brown or dark clay	1,482	32,181	33,663
G	**Sand over clay soils**	**180,162**	**212,364**	**392,526**
G1	Sand over sandy clay loam	9,096	45	9,141
G2	Bleached sand over sandy clay loam	59,294	46,366	105,660
G3	Thick sand over clay	104,318	79,389	183,707
G4	Sand over poorly structured clay	7,454	86,564	94,018
H	**Deep sands**	**223,127**	**157,810**	**380,937**
H1	Carbonate sand	12,127	0	12,127
H2	Siliceous sand	32,204	4	32,208
H3	Bleached siliceous sand	178,796	157,806	336,602
L	**Shallow soil on rock**	**12**	**333**	**345**
L1	Shallow soil on rock	12	335	345
M	**Deep uniform to gradational soils**	**1,164**	**7,646**	**8810**
M1	Deep sandy loam	848	37	885
M2	Deep friable gradational clay loam	308	7,263	7,571
M4	Deep hard gradational sandy loam	8	346	354
N	**Wet soils**	**42,785**	**28,362**	**71,147**
N2	Saline soil	41,531	27,796	69,327
N3	Wet soil (non to moderately saline)	1,254	566	1,820
NA	**Not Applicable (water, rock, unmapped)**	**59,740**	**5,746**	**65,486**
NA	Not Applicable (water, rock, unmapped)	59,740	5,746	65,486
TOTAL		**886,084**	**652,097**	**1,538,181**

7.3 Appendix III: Yield penalty in the Coonalpyn paddock

Area (hectares)		**pH 5.5 - 5.0**	**pH 4.9 - 4.5**	**pH <4.5**		
		42.87	27.03	0.51		
Assume	**Production losses (t/ha)**	**pH 5.5 - 5.0**	**pH 4.9 - 4.5**	**pH <4.5**		**Prices ($/t)**
	Wheat	0	0.2	0.4		260
	Barley	0.2	0.6	1.0		220
	Peas	0.2	0.4	1.0		380
	Lupins	0	0.2	0.4		300
	Beans	0.2	0.6	1.2		400
	Lentils	0.2	0.6	1.2		700
	Hay	0.2	0.4	0.8		180
	Canola	0.2	0.6	1.0		550
	Other (oats/ triticale)	0	0.2	0.4		230
	Pasture (acid sensitive)	0.2	0.6	1.0		120
	Pasture (Acid tolerant)	0	0.2	0.4		120
Assume	**Value of production losses ($)**	**pH 5.5 - 5.0**	**pH 4.9 - 4.5**	**pH <4.5**		**Total**
	Wheat	0	1,406	53		1,459
	Barley	1,886	3,568	112		5,566
	Peas	3,258	4,109	194		7,560
	Lupins	0	1,622	61		1,683
	Beans	3,430	6,487	245		10,162
	Lentils	6,002	11,353	428		17,783
	Hay	1,543	1,946	73		3,563
	Canola	4,716	8,920	281		13,916
	Other (oats/ triticale)	0	1,243	47		1,290
	Pasture (acid sensitive)	1,029	1,946	61		3,036
	Pasture(acid tolerant)	0	649	24		673
Total value of crop production losses						
	Assuming a Wheat, Barley, Beans, Wheat, Barley, Pasture (acid sensitive) the production loss is					
					$27,248	**$144/hectare**
	Annual production loss of				**$4,541**	**$24/ha/year**

7.4 Appendix IV:

Yield penalty: currently acidic or likely to become acidic in the next 5–10 years

Yield Penalty Model - Currently acidic or likely to become acidic in the 5-10 years							**Coorong**
Area of land inherently acidic, curently acidic or likely to become acidic in the next 5-10 years acid							117,825
Crop	Assume	31,813	hectares of inherently acidc, acidic or becoming acid under crop each year				
Assume that	43%	is at a pH 5.5 and not treated with lime (lime sales data)				13,678	hectares
Assume	65%	at pH 5.5 - 5.0 ($CaCl_2$)	8,890	hectares			
	29%	at pH 4.9 - 4.5 ($CaCl_2$)	3,967	hectares			
	6%	at pH <4.5 ($CaCl_2$)	821	hectares			
Assume	Crop	% area	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5		
	Wheat	26	2311	1031	213		
	Barley	25	2223	992	205		
	Peas	1.4	124	56	11		
	Lupins	3.6	320	143	30		
	Beans	3.6	320	143	30		
	Lentils	1	89	40	8		
	Hay	31.4	2791	1246	258		
	Canola	6	533	238	49		
	Other oats /triticale)	2	178	79	16		
		100	8890	3967	821		
Assume	Production losses (t/ha)		pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5		Prices ($/t)
	Wheat		0	0.2	0.4		260
	Barley		0.2	0.6	1		220
	Peas		0.2	0.4	1		380
	Lupins		0	0.2	0.4		300
	Beans		0.2	0.6	1.2		400
	Lentils		0.2	0.6	1.2		700
	Hay		0.2	0.4	0.8		180
	Canola		0.2	0.6	1		550
	Other (oats/ triticale)		0	0.2	0.4		230
Assume	Value of production losses ($)		pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5		Total
	Wheat		0	53634	22200		75834
	Barley		97790	130911	45155		273856
	Peas		9459	8442	4368		22268
	Lupins		0	8569	3547		12115
	Beans		25603	34275	14187		74065
	Lentils		12446	16661	6896		36004
	Hay		100493	89686	37122		227301
	Canola		58674	78547	27093		164314
	Other (oats/ triticale)		0	3650	1511		5160
	Total value of crop production losses		$ 890,917				
Pasture	Assume	86,012	hectares of inherently acidc, acidic or becoming acid under pasture each year				
Assume that	43%	is at a pH 5.5 and not treated with lime (lime sales data)				36,985	hectares
Assume	65%	at pH 5.5 - 5.0 ($CaCl_2$)	24,040	hectares			
	29%	at pH 4.9 - 4.5 ($CaCl_2$)	10,725	hectares			
	6%	at pH <4.5 ($CaCl_2$)	2,219	hectares			
Assume	Pasture	% area	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5		
	Acid sensitive	50	12020	5362	1110		
	Acid tolerant	50	12020	5362	1110		
Assume	Production losses (t/ha)		pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5		Prices ($/t)
	Acid sensitive		0.2	0.6	1		120
	Acid tolerant		0	0.2	0.4		120
Assume	Value of production losses ($)		pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5		Total
	Acid sensitive		288480	386064	133200		807744
	Acid tolerant		0	128688	53280		181968
	Total value of pasture production losses		$ 989,712				
	Total value of production losses		**$ 1,880,629**				

Yield Penalty Model - Currently acidic or likely to become acidic in the 5-10 years — Tatiara

Area of land inherently acidic, curently acidic or likely to become acidic in the next 5-10 years acid: 216,690

Crop

Assume 86,676 hectares of inherently acidc, acidic or becoming acid under crop each year

Assume that 43% is at a pH 5.5 and not treated with lime (lime sales data) — 37,271 hectares

Assume	65%	at pH 5.5 - 5.0 ($CaCl_2$)	20,976	hectares
	29%	at pH 4.9 - 4.5 ($CaCl_2$)	10,808	hectares
	6%	at pH <4.5 ($CaCl_2$)	2,236	hectares

Assume	Crop	% area	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5
	Wheat	18	3776	1945	402
	Barley	19	3985	2054	425
	Peas	0.6	126	65	13
	Lupins	0.7	147	76	16
	Beans	7	1468	757	157
	Lentils	1	210	108	22
	Hay	46.7	9796	5047	1044
	Canola	5	1049	540	112
	Other oats /triticale)	2	420	216	45
		100	20976	10808	2236

Assume	Production losses (t/ha)	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5	Prices ($/t)
	Wheat	0	0.2	0.4	260
	Barley	0.2	0.6	1	220
	Peas	0.2	0.4	1	380
	Lupins	0	0.2	0.4	300
	Beans	0.2	0.6	1.2	400
	Lentils	0.2	0.6	1.2	700
	Hay	0.2	0.4	0.8	180
	Canola	0.2	0.6	1	550
	Other (oats/ triticale)	0	0.2	0.4	230

Assume	Value of production losses ($)	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5	Total
	Wheat	0	101163	41858	143021
	Barley	175359	271065	93465	539889
	Peas	9565	9857	5098	24520
	Lupins	0	4539	1878	6418
	Beans	117466	181574	75130	374170
	Lentils	29366	45394	18782	93542
	Hay	352649	363408	150367	866423
	Canola	115368	178332	61490	355190
	Other (oats/ triticale)	0	9943	4114	14058

Total value of crop production losses $ 2,417,230

Pasture

Assume 130,014 hectares of inherently acidc, acidic or becoming acid under pasture each year

Assume that 43% is at a pH 5.5 and not treated with lime (lime sales data) — 55,906 hectares

Assume	65%	at pH 5.5 - 5.0 ($CaCl_2$)	36,338	hectares
	29%	at pH 4.9 - 4.5 ($CaCl_2$)	16,212	hectares
	6%	at pH <4.5 ($CaCl_2$)	3,354	hectares

Assume	Pasture	% area	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5
	Acid sensitive	50	18169	8106	1677
	Acid tolerant	50	8169	8106	1677

Assume	Production losses (t/ha)	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5	Prices ($/t)
	Acid sensitive	0.2	0.6	1	120
	Acid tolerant	0	0.2	0.4	120

Assume	Value of production losses ($)	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5	Total
	Acid sensitive	436056	583632	201240	1220928
	Acid tolerant	0	194544	80496	275040

Total value of pasture production losses $ 1,495,968

Total value of production losses $ 3,913,198

7.5 Appendix V: Yield Penalty: prone to acidification in the next 10 – 50 years

Yield Penalty Model - Prone to acidification in next 10 - 50 years	Coroong
Area of land inherently acidic, curently acidic or likely to become acidic in the next 10-50 years acid	255,448

Crop

Assume	68,970	hectares of inherently acidc, acidic or becoming acid under crop each year		
Assume that	43%	is at a pH 5.5 and not treated with lime (lime sales data)	29,657	hectares
Assume	65%	at pH 5.5 - 5.0 ($CaCl_2$)	19,277	hectares
	29%	at pH 4.9 - 4.5 ($CaCl_2$)	8,600	hectares
	6%	at pH <4.5 ($CaCl_2$)	1,779	hectares

Assume	Crop	% area	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5
	Wheat	26	5012	2236	463
	Barley	25	4819	2150	445
	Peas	1.4	270	120	25
	Lupins	3.6	694	310	64
	Beans	3.6	694	310	64
	Lentils	1	193	86	18
	Hay	31.4	6053	2700	559
	Canola	6	1157	516	107
	Other (oats/ triticale)	2	386	172	36
		100	19277	8600	1779

Assume	Production losses (t/ha)	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5	Prices ($/t)
	Wheat	0	0.2	0.4	260
	Barley	0.2	0.4	1	220
	Peas	0.2	0.4	1	380
	Lupins	0	0.2	0.4	300
	Beans	0.2	0.6	1.2	400
	Lentils	0.2	0.6	1.2	700
	Hay	0.2	0.4	0.8	180
	Canola	0.2	0.6	1	550
	Other (oats/ triticale)	0	0.2	0.4	230

Assume	Value of production losses ($)	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5	Total
	Wheat	0	116272	48104	164376
	Barley	212047	189200	97845	499092
	Peas	20511	18301	9464	48276
	Lupins	0	18576	7685	26261
	Beans	55518	74304	30741	160563
	Lentils	26988	36120	14944	78051
	Hay	217907	194429	80439	492775
	Canola	127228	170280	58707	356215
	Other (oats/ triticale)	0	7912	3273	11185
	Total value of crop production losses	$ 1,836,795			

Pasture

Assume	186,478	hectares of inherently acidc, acidic or becoming acid under pasture each year		
Assume that	43%	is at a pH 5.5 and not treated with lime (lime sales data)	80,185	hectares
Assume	65%	at pH 5.5 - 5.0 ($CaCl_2$)	52,120	hectares
	29%	at pH 4.9 - 4.5 ($CaCl_2$)	23,253	hectares
	6%	at pH <4.5 ($CaCl_2$)	4,811	hectares

Assume	Pasture	% area	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5
	Acid sensitive	50	26,060	11626	2405
	Acid tolerant	50	26,060	11626	2405

Assume	Production losses (t/ha)	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5	Prices ($/t)
	Acid sensitive	0.2	0.6	1	120
	Acid tolerant	0	0.2	0.4	120

Assume	Value of production losses ($)	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5	Total
	Acid sensitive	625440	837072	288600	1751112
	Acid tolerant	0	279024	115440	394464
	Total value of pasture production losses	$ 2,145,576			

Total value of production losses	$ 3,982,371
Total value of production loss: current and potential	$5,863,000

Yield Penalty Model - Prone to acidification in next 10 - 50 years

Tatiara

Area of land inherently acidic, curently acidic or likely to become acidic in the next 10-50 years acid	119,666

Crop

Assume	47,866	hectares of inherently acidc, acidic or becoming acid under crop each year		
Assume that	43%	is at a pH 5.5 and not treated with lime (lime sales data)	20,582	hectares
Assume	65%	at pH 5.5 - 5.0 ($CaCl_2$)	13,379	hectares
	29%	at pH 4.9 - 4.5 ($CaCl_2$)	5,968	hectares
	6%	at pH <4.5 ($CaCl_2$)	1,235	hectares

Assume	Crop	% area	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5
	Wheat	18	2408	1074	222
	Barley	19	2542	1134	235
	Peas	0.6	80	36	7
	Lupins	0.7	94	42	9
	Beans	7	937	418	86
	Lentils	1	134	60	12
	Hay	46.7	6248	2787	577
	Canola	5	669	298	62
	Other (oats/ triticale)	2	268	119	25
		100	13379	5968	1235

Assume	Production losses (t/ha)	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5	Prices ($/t)
	Wheat	0	0.2	0.4	260
	Barley	0.2	0.4	1	220
	Peas	0.2	0.4	1	380
	Lupins	0	0.2	0.4	300
	Beans	0.2	0.6	1.2	400
	Lentils	0.2	0.6	1.2	700
	Hay	0.2	0.4	0.8	180
	Canola	0.2	0.6	1	550
	Other (oats/ triticale)	0	0.2	0.4	230

Assume	Value of production losses ($)	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5	Total
	Wheat	0	55860	23119	78980
	Barley	111848	99785	51623	263256
	Peas	6101	5443	2816	14359
	Lupins	0	2507	1037	3544
	Beans	74922	100262	41496	216681
	Lentils	18731	25066	10374	54170
	Hay	224928	200668	83051	508647
	Canola	73585	98472	33963	206019
	Other (oats/ triticale)	0	5491	2272	7763

Total value of crop production losses $ 1,353,420

Pasture

Assume	71,800	hectares of inherently acidc, acidic or becoming acid under pasture each year		
Assume that	43%	is at a pH 5.5 and not treated with lime (lime sales data)	30,874	hectares
Assume	65%	at pH 5.5 - 5.0 ($CaCl_2$)	20,068	hectares
	29%	at pH 4.9 - 4.5 ($CaCl_2$)	8,953	hectares
	6%	at pH <4.5 ($CaCl_2$)	1,852	hectares

Assume	Pasture	% area	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5
	Acid sensitive	50	10,034	4476	926
	Acid tolerant	50	10,034	4476	926

Assume	Production losses (t/ha)	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5	Prices ($/t)
	Acid sensitive	0.2	0.6	1	120
	Acid tolerant	0	0.2	0.4	120

Assume	Value of production losses ($)	pH 5.5 - 5.0	pH 4.9 - 4.5	pH <4.5	Total
	Acid sensitive	240816	322272	111120	674208
	Acid tolerant	0	107424	44448	151872

Total value of pasture production losses $ 826,080

Total value of production losses $ 2,179,500

Total value of production loss: current and potential $6,092,698