Soil Properties under Tree Plantations, Crops and Pastures Irrigated with Paper Mill Effluent at Albury in 2012

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1. SUMMARY

In 1993 a plantation of radiata pine was established on agricultural land at Ettamogah for the re-use of effluent from the Norske Skog paper mill. Irrigation of trees commenced in 1995 and annual monitoring of tree condition, irrigation water and soil properties has been conducted as part of the EPA license agreement for the reuse of effluent. Harvesting of the tree plantation commenced in 2004 and was completed in 2012. Cleared plantation areas have either been replanted with a second rotation of radiata pine and eucalypts irrigated by drip-irrigation (79 ha) or were returned to agriculture to expand the area under crops and pastures irrigated by sprinkler systems at Ettamogah and adjacent farm land (266 ha).

Annual monitoring of soil profiles has been conducted since the project commenced to determine the long-term impacts of irrigation with effluent on soil properties in the root zones of the tree plantation at Ettamogah. Soil monitoring was expanded to include effluent irrigated crops and pastures on adjacent agricultural land since 2003. In general the re-use of mill effluent has increased pH, salinity, sodicity and sulphate in soil profiles while the impact on other soil properties has been relatively minor. In 2012 additional soil physical testing was carried out to determine the long-term impact of effluent on soil structure.

In 2012 seasonal rainfall (943 mm) was above average thus limiting the irrigation of trees (4.5 Ml/ha) and crops and pastures (2.2 Ml/ha); therefore salt loads were low compared with past years of low rainfall and high irrigation. The main findings for chemical and physical testing of soils are summarized below:

- Soil pH remained higher in irrigated soil profiles under trees (pH_{Ca} range 6.2 to 6.9) and crops and pastures (pH_{Ca} range 6.4 to 7.4) compared with the slightly more acidic conditions of unirrigated soils (pH_{Ca} range 5.5 to 6.5).
- Exchangeable sodium percentage (ESP) in soil profiles has declined and average ESP ranged from 4% in the surface soil to 24% in the sub-soil under trees and from 4% to 25% under irrigated crops and pastures. Irrigated and unirrigated surface soils were non-sodic (ESP < 6%). In contrast ESP in sub-soils under irrigated trees and crops and pastures remained high indicating strong sodic conditions at depth compared with unirrigated sub-soils (ESP range 6% to 13%).
- Average salinity in root zones of irrigated soils declined to 1.2 dS/m under trees but remained at 1.1 dS/m under crops and pastures. Salinity in root zones has declined in recent years of high rainfall and remained below the threshold value of 4.0 dS/m required by the EPA Load Based Licensing Protocol.
- Extractable sulphur in irrigated soils decreased to 15 mg/kg in surface soil but remained high at 207 mg/kg in the sub-soil under trees. Likewise extractable S declined to 11 mg/kg in surface soil and remained high at 192 mg/kg in the sub-soil under crops and pastures. This compared with levels of S in unirrigated soils of 12 mg/kg in surface soil and 58 mg/kg in the sub-soil.
- Slaking tests showed that the structural bonding of aggregates of both irrigated and unirrigated soils is inherently weak and large aggregates disintegrate easily into smaller particles under wet conditions from rainfall and irrigation with effluent.
- Dispersion tests in distilled water showed that the fine structure of both irrigated and unirrigated surface soils was stable but collapsed when soils became compacted. In contrast, irrigated sub-soils dispersed in water indicating that the fine structure can be expected to deteriorate when these soils are returned to conditions of natural rainfall and treatment with gypsum would be required to stabilize soil structure.
- Dispersion tests in effluent (EC 1.5 dS/m) showed that the fine structure of irrigated soils remained stable (no clay dispersion) even after compaction and for a wide range of sodicity in soil profiles.

Average salinity in the root zones of trees (1.2 dS/m) and crops and pastures (1.1 dS/m) in 2012 remained below the Load Base Licensing threshold level of 4.0 dS/m for the re-use scheme.

2. INTRODUCTION

Since 1995 effluent from the Norske Skog paper mill has been re-used to irrigate a radiata pine plantation and more recently agricultural land. Effluent from the mill is discharged to a large storage dam and then reticulated to irrigate the plantation using a drip irrigation system and agricultural crops and pastures using mobile sprinkler systems. Harvesting of the plantation commenced in 2004 and cleared areas have either been replanted with radiata pine and blue gum or were converted to crops and pastures. In 2012 rainfall was well above average and irrigation was applied at low rates to areas of new tree plantings (79 ha) and crops and pastures (266 ha).

Since the project commenced, annual monitoring of tree condition, irrigation water, and soil properties has been conducted as part of the EPA license agreement for the re-use of mill effluent at Ettamogah. The current monitoring program is based on site-specific protocols developed as part of a review of the re-use scheme (Hopmans 2006).

In 2012, soil samples were collected in the irrigated plantation of radiata pine and blue gum at Ettamogah. Soil samples were also collected from the areas of irrigated and unirrigated crops and pastures established on harvested tree plantations at Ettamogah and adjacent agricultural land at Maryvale, Rosevale and Davey Rd. This report presents the results of soil chemical and physical testing carried out in 2012.

3. METHODS

Soil samples were collected in August 2012 in accordance with the site-specific soil monitoring protocol developed as part of the EPA license agreement for the re-use of mill effluent at Ettamogah (Hopmans 2006).

Tree Plantation

Soil profile samples (0 - 10, 20 - 30, 50 – 60, and 80 - 90 cm) were collected from second rotation tree plantings irrigated with effluent including three monitoring plots (3.02, 3.11, 3.15) in radiata pine and one plot (1.26) in blue gum (*Eucalyptus saligna*) at Ettamogah.

Crops and Pastures

Soil profile samples (0 - 10, 20 - 30, and 50 - 60 cm) were collected in crops irrigated by mobile sprinkler systems and unirrigated crops in adjacent areas at the following locations:

- Ettamogah, former plantation areas converted to crops and pastures (irrigation resumed in 2007): irrigated (3) and unirrigated (5) plots. Additional sub-soil samples were collected at depth (80 – 90 cm).
- Maryvale (commenced 2003): irrigated (9) and unirrigated (5) plots.
- Rosevale (commenced 2004): irrigated (3) and unirrigated (3) plots.
- Davey Rd (commenced 2006): irrigated (4) and unirrigated (3) plots.

Soil Chemical Tests

Soil testing was carried out at the inorganic chemistry laboratory of the Department of Primary Industries at Macleod in Victoria using standard methods (Rayment and Higginson 1992). Soil tests included the following:

- pH in water and in 0.01 M $CaCl_2$ both at a soil/water ratio of 1:5
- Electrical conductivity (EC) at a soil/water ratio of 1:5
- Extractable chloride at a soil/water ratio of 1:5
- Acidified fluoride extractable phosphorus (Bray-2 P)
- Extractable sulphur in 0.01M calcium phosphate
- Total carbon and nitrogen by Dumas combustion (LECO CN Analyzer)
- Exchangeable cations using a compulsive exchange method (0.1M $BaCl_2$ – 0.1M NH_4Cl) after removal of soluble salts with aqueous ethanol (2 washes)

Soil Salinity

Salinity was measured as $EC_{1:5}$ (dS/m) on 1:5 soil-water extracts and EC_{se} was estimated using the site-specific relationship developed for soils at Ettamogah (Hopmans 2006):

$EC_{se} = 7.0 \times EC_{1:5}$ (n = 148, F = 2162, R^2 = 0.94)

Average salinity in root zones under trees (0 – 90 cm) and crops and pastures (0 – 60 cm) was calculated as a water-use-weighted (WUW) average EC_{se} based on weighting factors reflecting the gradient in plant water use with depth as published by Shaw (1999) and adapted for the soil monitoring protocol used at Ettamogah (Hopmans 2006).

Soil Physical Testing

In 2012 additional testing was carried out to determine changes in soil structural properties based on the Emerson slaking and dispersion tests (Emerson 2002). The structural stability of soil is assessed by rating the slaking of dry aggregates and the dispersion of clay particles after 2 and 20 hours in both distilled water and effluent in accordance with classification system as outlined by Emerson (2002). Effluent for these tests was collected from the four-day holding pond in September 2012 (pH 8.1 and EC 1.5 dS/m).

The slaking test is an indicator of the structural stability of large aggregates (or disintegration of aggregates) upon sudden wetting from rainfall or irrigation and reflects the degree of organic and inorganic bonding between soil particles. The break-down of weakly bonded aggregates into smaller particles reduces soil macro-porosity and potentially decrease hydraulic conductivity.

Slaking is often followed by soil dispersion, i.e. the break-down of the fine structure of soil in response to the swelling and separation of clay particles. The separation of clay particles (dispersion) increases and therefore soil structural stability decreases as the levels of monovalent cations (Na^+ and K^+) increase relative to divalent cations (Ca^{2+} and Mg^{2+}) for a given salt concentration in the soil solution. Clay dispersion is promoted by high ESP and is therefore common in sodic soils. Salinity however counteracts clay separation by compressing and flocculating clay particles, under these conditions soil structure remains stable (flocculated). The total ionic strength (salinity) at which the clay remains flocculated is defined as the threshold electrical conductivity (TEC) of the soil solution. The TEC for sub-soils of red gradational and yellow duplex soils at Ettamogah was determined experimentally at 1 dS/m (Hopmans 2006).

Dispersion tests were carried out on air-dry soil aggregates and re-moulded soil cubes formed when soil moisture was at field capacity. The physical re-moulding of wet soil separates clay particles and under these conditions results of the Emerson test reflect the dispersion of clay that might occur after soil compaction from heavy traffic such as tree harvesting equipment or agricultural machinery or other severe soil disturbance.

Slaking of large dry aggregates was assessed immediately after submersion in water and effluent and the stability of aggregates or disintegration into smaller aggregates was classed as: stable, partial slaking, or considerable slaking.

Soil dispersion was assessed 2 and 20 hours after submersion of dry aggregates and re-moulded soil cubes (compacted soil) in water and effluent. The degree of dispersion was rated in accordance with the classification system of Emerson (2002) summarized below.

- Dispersion of air-dry aggregates: severe (class 1), moderate to slight (class 2) and slight to nil (further testing using re-moulded soil cubes)
- Dispersion of re-moulded soil cubes: severe (class 3a), moderate to slight (class 3b), slight to nil (prepare 1:5 soil – water suspension to classify suspended clay)
- Soil-water suspension: clay remains in suspension, peptised (class 5) or clay coagulates, flocculated (class 6)

Data Analysis

Annual mean values of soil properties of profile layers under tree plantations were used to examine changes over time compared with initial values reflecting baseline conditions prior to irrigation. Annual monitoring of soil properties under crops and pastures provides a direct comparison of irrigated and unirrigated soils and analysis of variance procedures were used to interpret differences in soil profiles due to irrigation with effluent (Statview 1999).

4. RESULTS AND DISCUSSION

4.1. Tree Plantation

Irrigation

Plantation areas scheduled for harvesting were not irrigated for several years to reduce soil moisture and increase the bearing strength in order to minimize soil disturbance and compaction from harvesting equipment. Irrigation was resumed at low rates after the establishment of second rotation plantings of radiata pine and blue gum in 2010 and 2011. In 2012 rainfall (943 mm) was above the long-term average for the location (694 mm) and was preceded by a very wet year with 1166 mm of rainfall in 2011 (Figure 1). In 2012 irrigation of young trees was increased to 4.5 ML/ha and the total hydraulic load (rainfall plus irrigation: 13.9 Ml/ha) was higher compared with previous years (7.7 and 12.7 ML/ha). The annual load of N, P, Zn and salts (TDS) in 2012 was estimated at 14.4, 1.4, 0.13, and 5075 kg/ha respectively (Appendix 3). The salt load (5.1 t/ha) in 2012 was higher than the loads applied in the previous two years (1.1 and 1.7 t/ha).

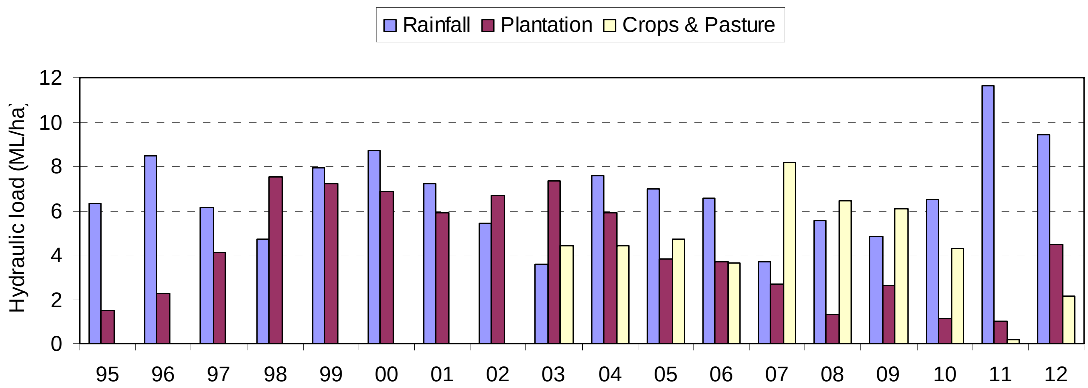

Figure 1. Seasonal rainfall (July – June) and annual irrigation (ML/ha) of the tree plantation at Ettamogah and crops and pastures at Ettamogah, Maryvale, Rosevale and Davey Road.

Chemical Properties

Soil profile samples were collected at four plots (1.26, 3.02, 3.11 and 3.15) under radiata pine and blue gum. The results of soil tests (Appendix 1) and comparison of average values for soil profile layers (Table 1) with past data (Figures 2 and 3) are summarized below:

- Average levels of total N in soil profiles decreased slightly in 2012 (Figure 2) compared with the previous year but in general there has been little change in total N since 2005. Total N in surface soils (0 – 10 cm) has declined from the pre-irrigation level of 1.8 g/kg in 1993 to 0.8 g/kg in 2012 while total N in sub-soils remains at similar levels.

- Extractable P in the surface soils (0 – 10 cm and 20 – 30 cm layers) remained low at 6 and 4 mg/kg in 2012 (Figure 2). The long-term decline in P of surface soils is consistent with the low rates of irrigation and P loads in recent years. Extractable P in the sub-soil (80 – 90 cm) remains at a similar level compared with the pre-irrigation level of 3 mg/kg.

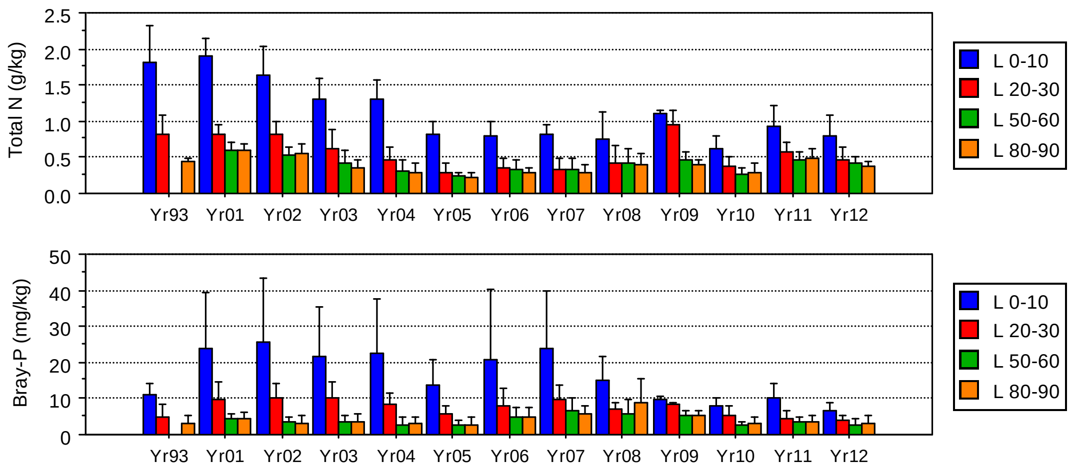

Figure 2. Average concentrations of total N and extractable P at four depths in soil profiles of the plantation irrigated with effluent since 1995. Bars indicate standard deviations.

- Average soil pH_{Ca} in profiles has increased from 4.7 in 1993 to 7.0 in 2002 and remained at this level until 2008 followed by a decline during years of low irrigation (Figure 3). In 2012 irrigation increased to 4.5 ML/ha and pH_{Ca} in the soil profile increased to 6.3 in the upper layers and to 6.8 in the sub-soils.

- Salinity (EC_{se}) of the surface soil (0 -10 cm) has declined to 0.6 dS/m similar to the initial level (0.8 dS/m) prior to irrigation in 1993 (Figure 3). Average salinity remained higher in sub-soils (1.9 and 2.6 dS/m) but salt levels have declined in recent years with high rainfall and low irrigation.

- Exchangeable Ca and Mg decreased slightly throughout the soil profile while exchangeable K increased marginally (Figure 3). The levels of exchangeable Ca, Mg and K in 2012 remained within the concentration ranges for the same four plots since 1998.

- Exchangeable Na in surface soils (0 – 10 cm, 20 - 30 cm) have declined to 0.3 and 0.5 cmolc/kg and are similar to the initial values (< 0.6 cmolc/kg) prior to irrigation in 1993. In contrast Na levels remained high in sub-soils (50 - 60 cm, 80 - 90 cm) at 2.6 and 3.0 cmolc/kg indicating little change during the recent wet years (Figure 3).

- ESP (exchangeable sodium percentage) has decreased in the surface soil to 4% indicating a return to non-sodic conditions prior to irrigation (Figure 3). In contrast ESP remained high in the sub-soils (24%) indicating that soil profiles remained sodic (ESP > 6%) at depth.

- Levels of extractable S in soil profiles decreased to 15 mg/kg in surface soils but remained high at 207 mg/kg in the sub-soil (Figure 3). In 2012 extractable S in surface soils was at a similar level prior to irrigation (14 mg/kg). In contrast, concentrations of S remained high in sub-soils although levels have declined (50 - 60 cm) consistent with transport of sulphate to lower depths in the soil profile.

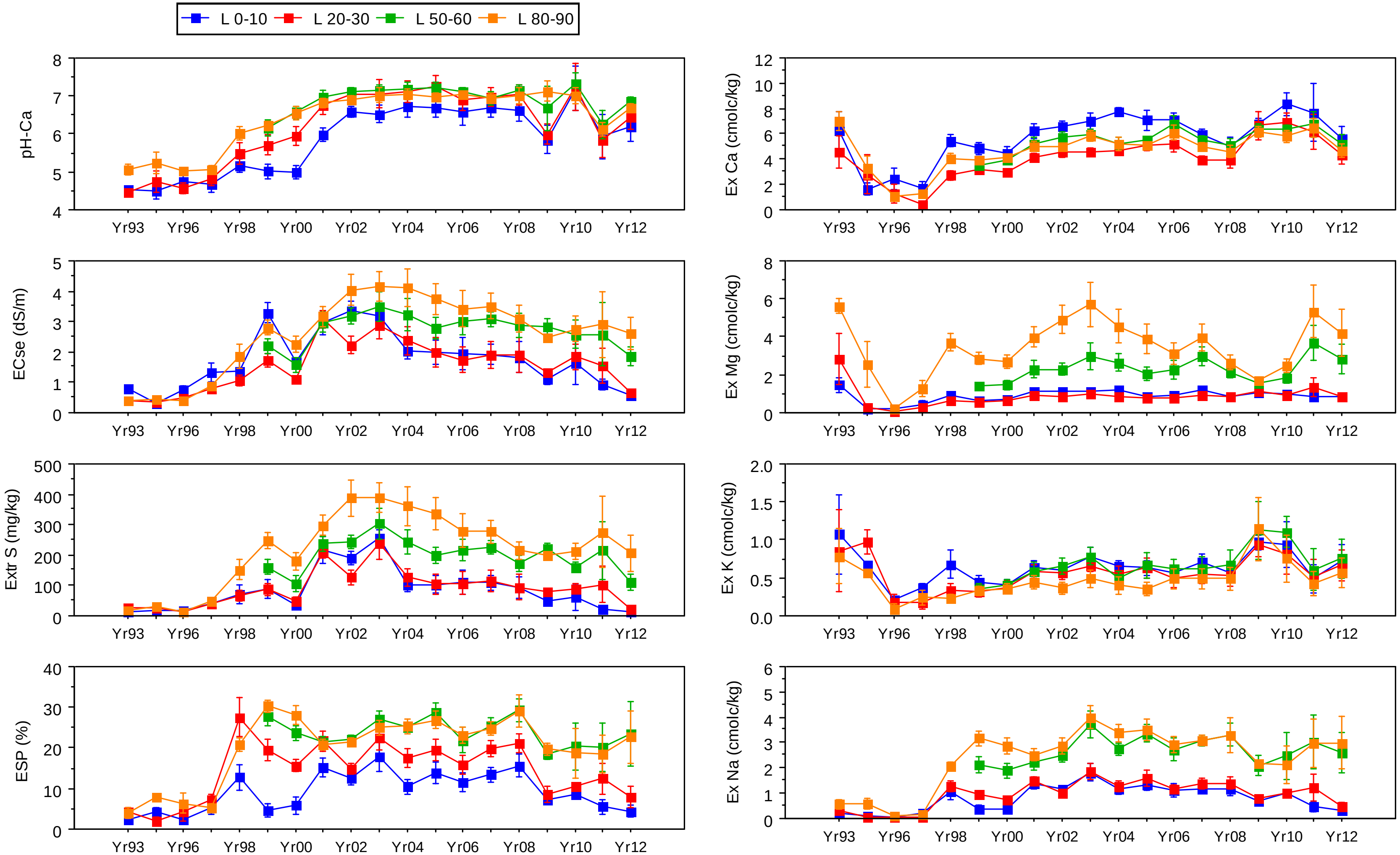

Figure 3. Average pH_{Ca}, EC_{se} (dS/m), extractable S (mg/kg), ESP (%), and exchangeable cations (cmolc/kg) in plantation soil profiles irrigated with effluent at Ettamogah since 1995 (bars indicate standard deviations). Monitoring of an additional soil profile layer (50 – 60 cm) commenced in 1999.

4.2. Crops and Pastures

Irrigation

In 2012 rainfall for the irrigation season (943 mm) was well above the long-term average (694 mm) for the location and was preceded by a very wet year (1166 mm) in 2011 (Figure 1). During this wet period crops and pastures were irrigated at low rates and less effluent applied in 2011 (0.2 ML/ha) and 2012 (2.2 ML/ha) compared with the preceding four years (Figure 1). The total hydraulic load (rainfall plus irrigation: 11.6 Ml/ha) in 2012 was similar as for previous years (range 10.1 to 12.0 Ml/ha). The average loads of N, P, Zn and salts (TDS) in 2012 were estimated at 7.0, 0.71, 0.07, and 2628 kg/ha respectively (Appendix 3). The salt load was low (2.6 t/ha) compared with previous annual loads of 14.9 t/ha (2007), 11.4 t/ha (2008) and 8.4 t/ha (2009) during years with low rainfall and high irrigation (Figure 1).

Chemical Properties

Results of the chemical analysis of soil profiles under crops and pastures at Ettamogah & Maryvale, Rosevale, and Davey Rd are presented in Appendix 1. Average results for profile layers are presented in Table 1 with values shown in red type where differences between irrigated and unirrigated plots were statistically significant ($P < 0.05$). Soil profile data for properties most affected by irrigation with effluent (pH_{Ca}, EC_{se}, ESP and extractable S) were compared with past data (Figures 4, 5 and 6) to determine long-term changes in soil properties since irrigation commenced at Maryvale (2003), Rosevale (2004), and Davey Rd (2006). At Ettamogah irrigation resumed in 2007 following the conversion from trees to crops and pastures.

Ettamogah and Maryvale

Comparison of irrigated (12) and unirrigated (10) plots indicated significant differences in pH, salinity (EC_{se}), exchangeable Na, ESP and extractable S in soil profiles due to irrigation with effluent (Table 1 and Figure 4). In contrast, levels of total carbon and nitrogen, extractable Cl and P, and exchangeable Ca, Mg and K were generally similar in irrigated and unirrigated soil profiles (Table1). The main effects of irrigation on soil properties are summarized below:

- Soil pH_{Ca} increased in surface soils indicating slightly alkaline conditions (pH 7 to 8) under irrigation in 2012 while conditions remained moderately acidic (pH 5 to 6) in the unirrigated soil (Figure 4). Soil pH_{Ca} has remained at around 6.6 in irrigated sub-soils indicating weakly acidic to neutral conditions for several years.

- Salinity (EC_{se}) in irrigated surface soils was low at 0.8 dS/m and slightly higher compared with 0.4 dS/m in unirrigated plots in 2012. Salinity remained high at 2.1 dS/m in the sub-soil compared with 0.9 dS/m for unirrigated sub-soils (Figure 4). Results indicate leaching of salts from surface soils into the sub-soil under low salt loads and high seasonal rainfall in 2011 and 2012.

- Exchangeable Na in surface soils has declined to similar levels as in unirrigated soils but remained higher in irrigated sub-soils (Table 1). Levels of exchangeable Ca were slightly higher in irrigated surface soils but exchangeable Mg and K were similar in irrigated and unirrigated soil profiles.

- Sodicity (ESP) was low (4%) in irrigated surface soils (0 – 10 cm) indicating non-sodic conditions (ESP < 6%). In contrast conditions were moderately sodic in sub-soils with ESP at 12% (20 – 30 cm) while strong sodic conditions prevailed with high ESP (27%) at depth (Figure 4). Unirrigated surface soils remained non-sodic (Figure 4) but sub-soils were moderately sodic (ESP 13%).

- Levels of extractable S in surface soils have declined to 11 mg/kg (0 – 10 cm) and 20 mg/kg in sub-soil (20 – 30 cm) and were at similar levels in unirrigated soils (Figure 4). In contrast levels remained high at 162 mg/kg at depth (50 – 60 cm).

Rosevale

Irrigation with effluent at Rosevale commenced in 2004 and comparison of irrigated (3 plots) and unirrigated (3 plots) indicate significant changes in soil pH, salinity (EC_{se}), ESP and extractable S while other soil properties were generally not affected by irrigation (Table 1 and Figure 5). The impacts of irrigation on soil properties in 2012 are summarized below:

- Soils (0 – 10 and 20 – 30 cm) remained slightly alkaline (pH_{ca} 7.4 and 7.1) compared with the moderately acidic conditions (pH_{Ca} 5.7 and 5.5) in unirrigated soils (Table 1). Likewise the pH of sub-soils (50 – 60 cm) remained higher (pH_{Ca} 6.4) compared with the more acidic conditions in unirrigated sub-soils (pH_{Ca} 5.1).

- Salinity (EC_{se}) in irrigated soils was low at 0.7 and 0.8 dS/m (0 – 10 and 20 – 30 cm) but remained higher compared with 0.4 dS/m in unirrigated soils (Table 1). Salinity in sub-soil has declined in recent years (Figure 5) but levels remained high at 2.9 dS/m compared with 0.9 dS/m in unirrigated sub-soil.

- Exchangeable Na was similar in the surface soil (0 – 10 cm) of irrigated and unirrigated plots but increased with depth in irrigated soils (Table 1). Levels of exchangeable Ca were slightly higher in irrigated soil while exchangeable Mg and K were similar in irrigated and unirrigated soil profiles.

- Sodicity (ESP) in surface soils declined to 4% (0 – 10 cm) but increased to 16% (20 – 30 cm) and 24% in the sub-soil (Table 1). The surface soil was no longer sodic (ESP < 6%) but soils remained strongly sodic at lower depths compared with unirrigated soils.

- Extractable S in irrigated surface soils was low at 11 mg/kg (0 – 10 cm) and 32 mg/kg (20 – 30 cm) but remained high at 194 mg/kg at depth (50 – 60 cm) (Table 1). Levels of extractable S were similar in surface soils of irrigated and unirrigated plots but remained higher in irrigated sub-soils (Figure 5).

Davey Rd

Soil monitoring at Davey Rd commenced in 2005 prior to the start of irrigation in April 2006. Comparison of irrigated (4 plots) and unirrigated (3 plots) soils indicated significant changes in soil pH, salinity (EC_{se}), sodicity (ESP) and extractable S due to effluent (Table 1 and Figure 6). In contrast, other soil properties were generally not affected by irrigation. The effects of irrigation on soil properties in 2012 are summarized below:

- Surface and sub-soils remained slightly acidic (pH_{Ca} 7.0 and 6.6) compared with strongly acidic conditions in unirrigated soils (Table 1). Soil pH declined in irrigated sub-soils at depth but remained higher compared with unirrigated soils (Figure 6).

- Salinity (EC_{se}) in surface soils remained low at 0.7 dS/m (0 – 10 cm) and 0.8 dS/m (20 – 30 cm) and levels were similar in unirrigated plots (Figure 6). In contrast, salinity remained high at 2.6 dS/m in irrigated sub-soil (50 – 60 cm) compared with unirrigated plots (0.8 dS/m).

- Exchangeable Na was higher throughout the soil profile of irrigated compared with unirrigated plots (Table 1). Levels of exchangeable Ca and Mg were slightly higher in irrigated soils while exchangeable K was similar in irrigated and unirrigated soil profiles.

- Sodicity (ESP) remained higher in soil profiles of irrigated compared with unirrigated plots (Table 1). ESP decreased to 4% in the surface soil (0 – 10 cm) but levels remained high at 17% (20 – 30 cm) and 22% (50 – 60 cm) indicating strong sodic conditions in irrigated sub-soils (Figure 6).

- Extractable S in irrigated surface soils was low at 11 mg/kg (0 – 10 cm) and 24 mg/kg (20 – 30 cm) and levels were similar in unirrigated plots (Table 1). In contrast, extractable S remained high at 221 mg/kg in irrigated sub-soils (Figure 6).

Table 1. Average pH, EC, total C and N, extractable Cl, P and S, and exchangeable cations in soil profiles under trees, crops and pasture in 2012.

Site	Treatment	Layer	pH-w	pH-Ca	EC1:5	EC_{se}	Extr Cl	Total C	Total N	Bray-P	Extr S	Exch Ca	Exch Mg	Exch K	Exch Na	Sum Cats	ESP	Exch Ca/Mg
		cm			dS/m	dS/m	mg/kg	g/kg	g/kg	mg/kg	mg/kg	cmolc/kg	cmolc/kg	cmolc/kg	cmolc/kg	cmolc/kg	%	
Ettamogah	Effluent#	0-10	7.2	6.2	0.08	0.6	7	10.5	0.79	6	15	5.7	0.9	0.7	0.3	7.6	4	6.6
Plantation	Effluent	20-30	7.5	6.4	0.09	0.7	5	5.7	0.47	4	24	4.4	0.8	0.7	0.5	6.4	8	5.1
	Effluent	50-60	8.0	6.9	0.27	1.9	15	4.0	0.41	3	12	5.2	2.8	0.8	2.6	11.4	24	2.2
	Effluent	80-90	7.6	6.7	0.38	2.6	22	3.4	0.39	3	207	4.7	4.2	0.6	3.0	12.4	23	1.5
Ettamogah Crops	Nil	0-10	6.6	5.7	0.06	0.4	4	9.7	0.73	25	10	4.4	0.7	0.3	0.1	5.5	2	8.3
& Maryvale	Nil	20-30	6.7	5.8	0.06	0.4	5	4.9	0.39	9	16	3.6	0.9	0.3	0.3	5.0	5	4.7
	Nil	50-60	7.0	6.0	0.12	0.9	9	3.4	0.35	3	58	3.9	3.8	0.3	1.3	9.3	13	1.2
Ettamogah Crops	Effluent#	0-10	8.2	7.5	0.11	0.8	5	9.8	0.78	32	11	6.6	0.9	0.5	0.3	8.3	4	7.6
& Maryvale	Effluent	20-30	8.4	7.4	0.12	0.8	8	4.1	0.37	9	20	3.8	0.8	0.4	0.6	5.7	12	4.8
	Effluent	50-60	7.6	6.6	0.30	2.1	19	2.9	0.34	4	162	3.7	3.6	0.3	2.8	10.4	27	1.7
Rosevale	Nil	0-10	6.4	5.7	0.06	0.5	3	13.2	0.94	30	6	4.8	0.4	0.2	0.1	5.5	1	11.3
	Nil	20-30	6.5	5.5	0.05	0.4	4	4.3	0.30	10	7	2.4	1.1	0.1	0.1	3.8	3	4.3
	Nil	50-60	6.3	5.1	0.09	0.6	11	5.0	0.40	7	33	3.3	6.6	0.2	0.9	11.0	8	0.5
Rosevale	Effluent#	0-10	8.1	7.4	0.11	0.7	9	10.0	0.74	21	11	6.4	0.7	0.2	0.3	7.7	4	8.9
	Effluent	20-30	8.2	7.1	0.16	0.8	12	4.5	0.33	6	32	4.5	1.6	0.1	1.3	7.6	16	3.3
	Effluent	50-60	7.3	6.4	0.41	2.9	17	5.4	0.47	6	194	4.7	5.2	0.2	3.2	13.2	24	0.9
Davey Rd	Nil	0-10	5.3	4.6	0.13	0.9	28	10.9	0.86	35	25	1.9	0.4	0.7	0.1	3.0	2	5.9
	Nil	20-30	5.3	4.5	0.09	0.6	25	4.4	0.33	12	22	1.2	0.4	0.4	0.1	2.1	3	3.7
	Nil	50-60	5.8	5.1	0.11	0.8	22	3.5	0.32	4	53	3.3	3.5	0.5	0.5	7.7	6	1.0
Davey Rd	Effluent#	0-10	7.8	7.0	0.10	0.7	8	10.7	0.73	29	11	5.8	0.9	0.5	0.3	7.5	4	6.5
	Effluent	20-30	7.9	6.6	0.12	0.8	9	4.2	0.29	7	24	2.9	2.3	0.2	1.1	6.6	17	2.6
	Effluent	50-60	6.7	6.0	0.38	2.6	18	3.6	0.30	5	221	3.4	3.6	0.3	2.1	9.4	22	1.0

Values in red type indicate statistically significant differences (P<0.05) compared with the value for the corresponding unirrigated soil layer.

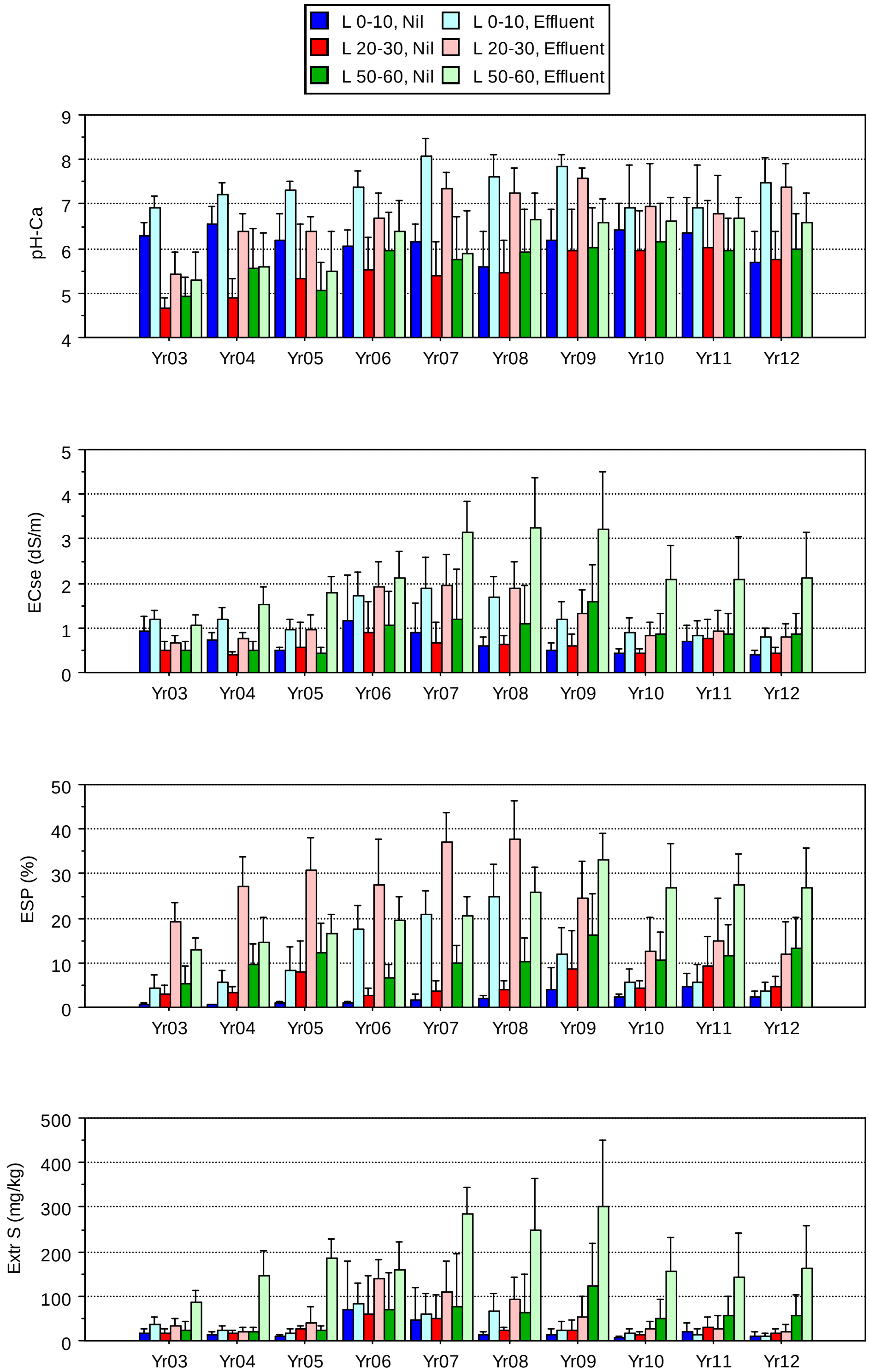

Figure 4. Average soil pH (calcium chloride), EC_{se} (dS/m), ESP (%), and extractable sulphur (mg/kg) at three depths in soil profiles of control (nil irrigation) and effluent irrigated crops and pastures at Ettamogah and Maryvale. Bars indicate standard deviations.

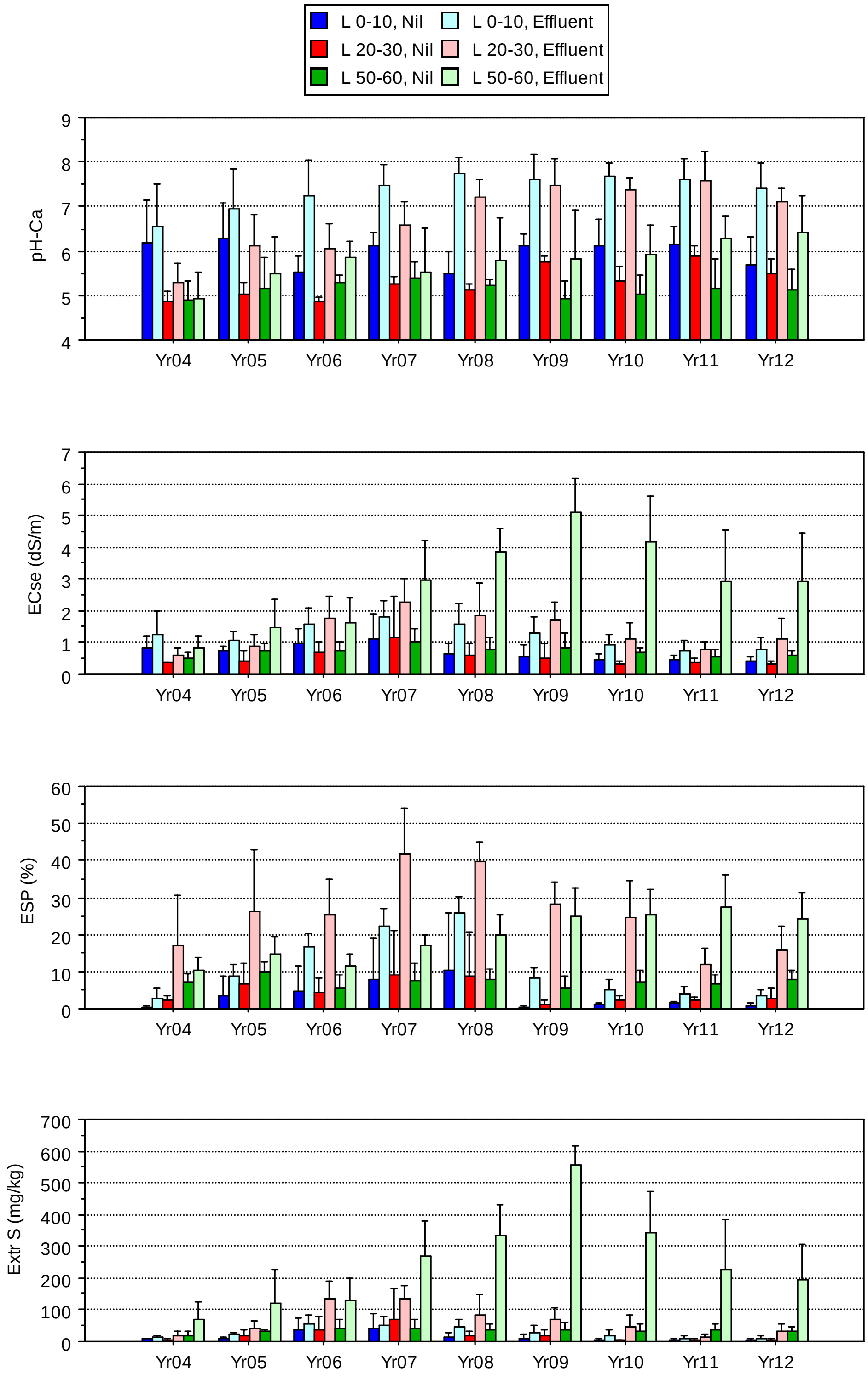

Figure 5. Average soil pH (calcium chloride), EC_{se} (dS/m), ESP (%), and extractable sulphur (mg/kg) at three depths in soil profiles of control (nil irrigation) and effluent irrigated crops and pastures at Rosevale. Bars indicate standard deviations.

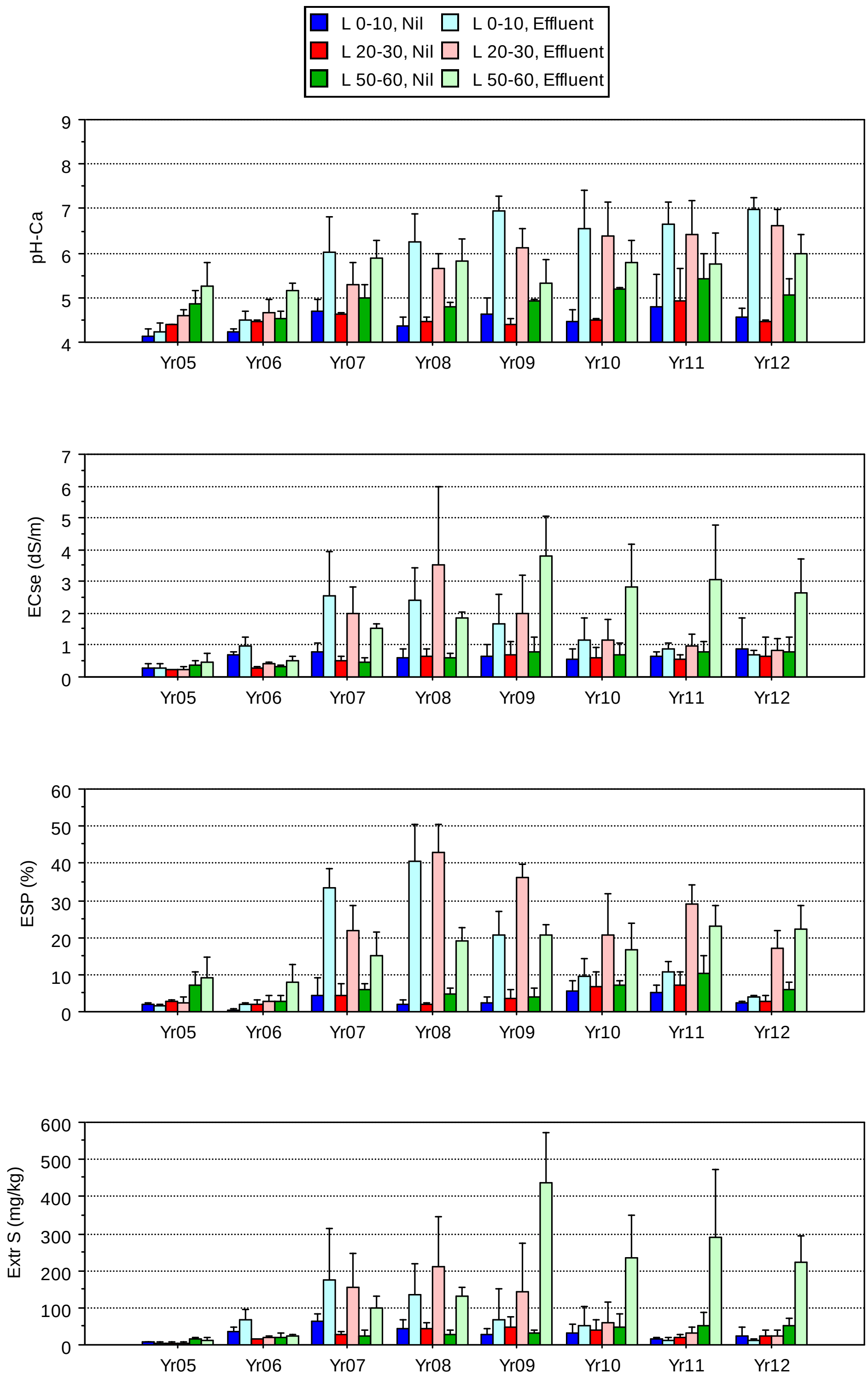

Figure 6. Average soil pH (calcium chloride), EC_{se} (dS/m), ESP (%), and extractable sulphur (mg/kg) at three depths in soil profiles of control (nil irrigation) and effluent irrigated crops and pastures at Davey Rd. Bars indicate standard deviations.

4.3. Salinity in Root Zones of Trees, Crops and Pastures

Average water-use weighted salinity (WUW EC_{se}) in soil profiles of trees and agricultural crops were calculated in accordance with the soil monitoring protocol for the effluent re-use scheme (Appendix 2). Average salinity in the root zones of irrigated tree plantations and irrigated and unirrigated agricultural crops and pastures are shown in Table 2.

- Average salinity in the root zones of trees in 2012 was estimated at 1.2 ± 0.2 dS/m (Table 2) and was below the salinity threshold level of 4.0 dS/m as required by the EPA Load Based Licensing Protocol. Long-term monitoring of the effluent irrigated plantation showed that root zone salinity decreased in 2012 compared with previous years (Figure 7).

- Average salinity in the root zones of crops and pastures irrigated with effluent at Ettamogah and Maryvale, Rosevale, and Davey Rd was estimated at 1.1 ± 0.4 dS/m (Table 2) and was below the threshold value of 4.0 dS/m. Root zone salinity has decreased since 2008 (Figure 7) in response to lower salt loads and high seasonal rainfall in recent years.

- Average salinity in the root zones of unirrigated crops and pastures at Ettamogah, Maryvale, Rosevale and Davey Rd was estimated at 0.5 ± 0.3 dS/m (Table 2).

Table 2. Average water-use weighted salinity (WUW EC_{se}) in root zones under trees, crops and pastures irrigated with paper mill effluent in 2012.

Site	Irrigated	WUW EC_{se} (dS/m)			
	(yrs)	Average	Std Dev[#]	Plots (n)	CoVar[†] (%)
Tree Plantation					
Ettamogah – Pine & Eucalypt	17	**1.2**	**0.2**	4	19
Crops & Pastures					
Ettamogah & Maryvale	10	1.0	0.3	12	32
Rosevale	9	1.3	0.7	3	50
Davey Rd	7	1.1	0.4	4	34
Average Crops & Pastures		**1.1**	**0.4**	19	35
Unirrigated					
Crops & Pastures		**0.5**	**0.3**	16	63

[#] Std Dev: standard deviation
[†] CoVar: coefficient of variation

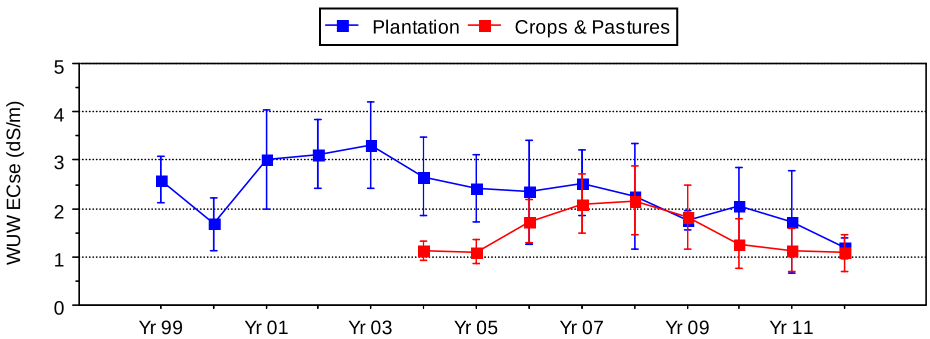

Figure 7. Average salinity (WUW EC_{se}) in the root zones of trees (0 – 90 cm) and crops and pastures (0 – 60 cm) irrigated with paper mill effluent. Bars indicate standard deviations.

4.4. Soil Structure

In 2012 additional physical testing of soils was carried out to determine the long-term impact of irrigation with effluent on the structural properties of soils. The stability of soil aggregates and clay dispersion were tested in both distilled water and effluent using the procedures outlined by Emerson (2002). Effluent used for these tests was collected from the four-day holding pond in September 2012 (pH 8.1 and EC 1.5 dS/m). The tests evaluate the structural stability of the soils under conditions of natural rainfall and irrigation with effluent. The results for slaking of dry aggregates in water and effluent and the dispersion of dry and re-moulded (compacted) aggregates of irrigated and unirrigated soils are presented in Appendix 4.

Slaking

The slaking tests showed considerable break-down of large aggregates into smaller particles and single grains (sand) in both water and effluent (Appendix 4). Results were similar for irrigated and unirrigated soils irrespective of the level of salinity or sodicity. This suggests that the organic bonding of aggregates of the soils at Ettamogah is comparatively weak and large aggregates disintegrate easily into smaller soil particles under rainfall or irrigation. The break-down of large aggregates into smaller particles under wet conditions appears to be a common characteristic of the soils at Ettamogah irrespective of irrigation with effluent.

Cultural practices that enhance soil organic matter and reduce physical disturbance of soils can be expected to improve the structural stability of soil aggregates. Therefore crop management practices such as stubble retention and minimum tillage would benefit soil structure in the long term. Likewise retention of harvesting residues in tree plantations and minimum soil disturbance at establishment by pit planting rather than deep ripping would enhance soil organic matter.

Dispersion

Dispersion of clay particles is promoted by high levels of exchangeable Na (ESP, sodicity) while the total ionic strength (salinity) of the soil solution counteracts dispersion by compressing and flocculating clay particles. Soil testing in 2012 showed that surface soils (0 - 10 cm) have become less saline and non-sodic (ESP < 6%) after several years of high rainfall and low irrigation with effluent. Likewise salinity and sodicity of sub-soils (20 – 30 cm and 50 – 60 cm) has declined although average levels remained higher in irrigated soils (EC_{se} 0.8 and 2.3 dS/m and ESP 13% and 25%) compared with unirrigated soils (EC_{se} 0.4 and 0.8 dS/m and ESP 4% and 11%).

The gradient in salinity and sodicity with depth in soil profiles in 2012 was reflected in the results for dispersion tests of surface and sub-soils in distilled water. In contrast, dispersion tests in effluent showed little, if any, clay dispersion in soil profiles indicating that the fine structure of soils remained stable under irrigation with effluent.

<u>Dispersion tests in distilled water</u>:

- Clay dispersion in distilled water of irrigated and unirrigated soils varied considerably with depth and the distribution of plots across the range of dispersion classes is shown separately for each depth in Figure 8.
- Dispersion of surface soils (0 - 10 cm) was negligible for dry aggregates and was moderate to severe in compacted soil of irrigated plots (severe 13% and moderate 87%) and similar to dispersion of unirrigated soil (severe 6%, moderate 75% and slight 19%).
- Dispersion of dry aggregates and compacted sub-soil (20 – 30 cm) of irrigated soils was severe to moderate (91%) while clay remained flocculated in a few plots (9%) with low sodicity (ESP < 6%). In contrast dispersion of dry aggregates of unirrigated soil was negligible but increased in compacted soil to moderate or severe (63%) while clay remained flocculated in a number of non-sodic plots (37%).
- Dispersion of dry aggregates and compacted sub-soil (50 – 60 cm) of irrigated soils was severe to moderate (74%) but clay remained flocculated in several plots (26%) with slightly lower sodicity (ESP < 20%) and higher salinity (EC_{se} > 2 dS/m). There was moderate to severe dispersion of dry aggregates and compacted sub-soils in a

several unirrigated plots (25%) with sodic sub-soils (ESP 25%) but clay remained flocculated in the majority of plots (75%) with low sodicity (ESP 8%).

Dispersion of dry surface soils in water (natural rainfall) was slight and similar for both irrigated and unirrigated soils but clay dispersion increased in re-moulded soil indicating that the fine structure of soils can be expected to deteriorate when surface soils become compacted. In contrast, dispersion of irrigated sub-soils was moderate to severe in both dry and compacted soils indicating that under present conditions of salinity and sodicity, the fine structure of sub-soils can be expected to deteriorate when irrigation with effluent ceases and soils are returned to conditions of natural rainfall.

Results indicate the need for ameliorative treatment of soils with gypsum of areas no longer required for the re-use of effluent. Furthermore soil compaction increased dispersion and therefore cultural practices that minimize physical soil disturbance need to be adopted to reduce clay dispersion and soil loss from erosion.

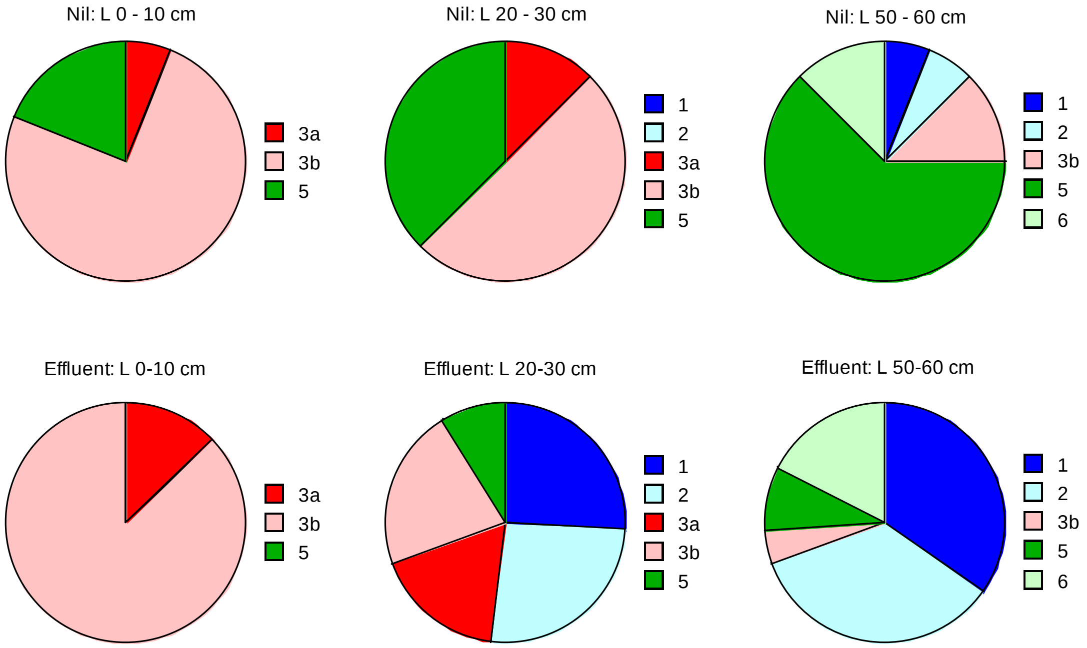

Figure 8. Proportion of irrigated and unirrigated plots (depths 0 – 10 cm, 20 – 30 cm, 50 – 60 cm) with clay dispersion of dry soil aggregates in distilled water rated as severe (class 1) or moderate (class 2) and dispersion of compacted soil in water rated as severe (class 3a), moderate (class 3b) or no dispersion with clay suspensions either peptised (class 5) or flocculated (class 6).

<u>Dispersion tests in effluent</u>:

- Clay dispersion of dry and compacted soil in effluent (EC 1.5 dS/m) was negligible with clay particles remaining strongly bonded (classes 5 and 6) throughout the profiles of irrigated and unirrigated soils (Appendix 4). Therefore clay particles and the fine structure of soils can be expected to remain stable under irrigation provided the EC of the effluent exceeds the TEC of 1 dS/m.

5. CONCLUSIONS

In 2012 soil testing was carried out as part of the environmental monitoring program for the waste water re-use scheme to determine the effects of irrigation with effluent on soil properties in the root zones of trees, crops and pastures. Annual monitoring of soils has shown that irrigation increased pH, salinity, sodicity and sulphate in soil profiles while the effects on other properties have been relatively minor. Additional soil physical tests were conducted to determine the long-term impact of effluent on soil structure.

In 2012 seasonal rainfall (943 mm) was above average thus limiting the irrigation of trees (4.5 Ml/ha) and crops and pastures (2.2 Ml/ha); therefore salt loads were low compared with past years of low rainfall and high irrigation. In addition salinity of effluent was low in 2012 (EC 1.3 mS/cm) compared with previous years (EC range 1.7 to 2.1 mS/cm) and this would have contributed to the lower salt load. The recent years of high rainfall and low irrigation have reduced pH, salinity, sodicity and sulphate in surface soils but conditions in sub-soils were only marginally affected. The results for soil chemical and physical testing conducted in 2012 are summarized below:

- Soil pH remained higher in irrigated soil profiles under trees (pH_{Ca} range 6.2 to 6.9) and crops and pastures (pH_{Ca} range 6.4 to 7.4) compared with the slightly more acidic conditions of unirrigated soils (pH_{Ca} range 5.5 to 6.5).
- Exchangeable sodium percentage (ESP) in soil profiles has declined and average ESP ranged from 4% in the surface soil to 24% in the sub-soil under trees and from 4% to 25% under irrigated crops and pastures. Irrigated (ESP 4%) and unirrigated (ESP 2%) surface soils were non-sodic (ESP < 6%). In contrast ESP in sub-soils under irrigated trees and crops and pastures remained high indicating strong sodic conditions at depth compared with unirrigated sub-soils (ESP range 6% to 13%).
- Average salinity in root zones of irrigated soils declined to 1.2 dS/m under trees but remained at 1.1 dS/m under crops and pastures. Salinity in root zones has declined in recent years of high rainfall and remained below the threshold value of 4.0 dS/m required by the EPA Load Based Licensing Protocol.
- Extractable sulphur in irrigated soils decreased to 15 mg/kg in surface soil but remained high at 207 mg/kg in the sub-soil under trees. Likewise extractable S declined to 11 mg/kg in surface soil and remained high at 192 mg/kg in the sub-soil under crops and pastures. This compared with levels of S in unirrigated soils of 12 mg/kg in surface soil and 58 mg/kg in the sub-soil.
- Slaking tests showed that the structural bonding of aggregates of both irrigated and unirrigated soils is inherently weak and large aggregates disintegrate easily into smaller particles under wet conditions from rainfall and irrigation with effluent.
- Dispersion tests in distilled water showed that the fine structure of both irrigated and unirrigated surface soils was stable but collapsed when soils became compacted. In contrast, irrigated sub-soils dispersed in water indicating that the fine structure can be expected to deteriorate when these soils are returned to conditions of natural rainfall and treatment with gypsum would be required to stabilize soil structure.
- Dispersion tests in effluent (EC 1.5 dS/m) showed that the fine structure of irrigated soils remained stable (no clay dispersion) even after compaction and for a wide range of sodicity in soil profiles.

Average salinity in the root zones of trees (1.2 dS/m) and crops and pastures (1.1 dS/m) in 2012 remained below the Load Base Licensing threshold level of 4.0 dS/m for the re-use scheme.

6. REFERENCES

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Appendix 1. Results of chemical analysis of soils of the tree plantation at Ettamogah and crops and pastures at Ettamogah, Maryvale, Rosevale and Davey Rd in 2012.

Plantation at Ettamogah

Species & Plot	Treatment	Depth (cm)	pH-Ca	pH-W	$EC_{1:5}$ (dS/m)	Extr Cl (mg/kg)	Total C (g/kg)	Total N (g/kg)	Bray-P (mg/kg)	Extr S (mg/kg)	Exch Ca (cmolc/kg)	Exch Mg (cmolc/kg)	Exch K (cmolc/kg)	Exch Na (cmolc/kg)
Blue gum														
1.26	Irrigated	0-10	7.2	8.4	0.09	5	7.1	0.54	8	12	4.6	0.9	0.5	0.4
1.26	Irrigated	20-30	7.3	8.6	0.10	8	3.4	0.29	4	22	2.7	0.6	0.4	0.7
1.26	Irrigated	50-60	7.2	8.6	0.28	19	3.0	0.33	3	96	2.8	2.3	0.3	4.6
1.26	Irrigated	80-90	6.9	8.1	0.38	19	2.6	0.35	2	184	3.2	4.7	0.2	5.7
Radiata pine														
3.02	Irrigated	0-10	6.3	7.2	0.09	13	16.9	1.16	9	10	8.2	1.0	1.1	0.3
3.02	Irrigated	20-30	6.1	7.1	0.10	8	8.4	0.66	6	26	5.8	1.0	1.0	0.5
3.02	Irrigated	50-60	6.9	7.6	0.38	22	5.0	0.48	5	187	6.1	2.1	1.3	1.6
3.02	Irrigated	80-90	6.8	7.5	0.40	33	4.4	0.44	6	218	5.1	2.4	1.0	1.7
3.11	Irrigated	0-10	5.4	6.4	0.10	9	10.6	0.90	5	36	5.5	0.9	1.1	0.5
3.11	Irrigated	20-30	6.0	7.0	0.12	4	6.5	0.58	3	43	5.4	1.1	1.0	0.7
3.11	Irrigated	50-60	6.7	7.8	0.17	8	4.9	0.50	3	63	6.6	1.9	1.1	1.1
3.11	Irrigated	80-90	6.6	7.6	0.18	8	4.0	0.44	4	69	5.8	2.2	0.8	1.2
3.15	Irrigated	0-10	5.9	6.8	0.04	3	7.3	0.57	4	3	4.3	0.6	0.3	0.1
3.15	Irrigated	20-30	6.3	7.2	0.04	1	4.6	0.36	2	3	3.5	0.7	0.2	0.1
3.15	Irrigated	50-60	6.7	7.9	0.23	11	3.0	0.34	1	103	5.1	5.1	0.3	3.1
3.15	Irrigated	80-90	6.4	7.1	0.55	29	2.7	0.31	1	357	4.7	7.4	0.2	3.4

Wheat, sorghum and pasture at Ettamogah

Plot	Treatment	Depth (cm)	pH_{Ca}	pH_{W}	$EC_{1:5}$ (dS/m)	Extr Cl (mg/kg)	Total C (g/kg)	Total N (g/kg)	Bray-P (mg/kg)	Extr S (mg/kg)	Exch Ca (cmolc/kg)	Exch Mg (cmolc/kg)	Exch K (cmolc/kg)	Exch Na (cmolc/kg)
1.02	Unirrigated	0-10	6.5	7.5	0.05	4	8.7	0.72	15	3	4.7	0.9	0.4	0.1
1.02	Unirrigated	20-30	6.9	8.3	0.07	4	4.3	0.38	4	5	3.9	0.9	0.5	0.5
1.02	Unirrigated	50-60	7.0	8.4	0.17	7	3.2	0.37	4	62	4.3	2.1	0.5	2.3
1.02	Unirrigated	80-90	6.8	7.9	0.25	12	3.5	0.41	5	132	4.1	3.3	0.4	2.7
1.03	Irrigated	0-10	6.0	7.3	0.06	8	10.4	0.82	22	7	3.8	0.9	0.5	0.3
1.03	Irrigated	20-30	6.6	7.9	0.05	7	4.2	0.34	13	8	2.3	0.6	0.2	0.2
1.03	Irrigated	50-60	6.9	8.2	0.22	13	3.5	0.36	4	87	4.3	3.7	0.4	3.3
1.03	Irrigated	80-90	6.8	7.8	0.46	21	2.8	0.31	3	255	3.9	6.5	0.2	4.2
1.09	Unirrigated	0-10	4.7	5.7	0.07	9	13.4	0.97	11	14	4.2	1.1	1.0	0.2
1.09	Unirrigated	20-30	5.0	5.9	0.08	5	6.1	0.56	5	34	4.5	1.4	1.0	0.3
1.09	Unirrigated	50-60	6.5	7.8	0.11	4	6.5	0.57	5	26	5.2	1.9	0.9	1.3
1.09	Unirrigated	80-90	6.8	8.2	0.14	6	6.0	0.53	5	42	5.2	2.2	0.7	1.9
MVP5-2.03	Irrigated	0-10	6.8	7.9	0.09	7	9.2	0.69	31	14	6.1	1.0	0.7	0.4
MVP5-2.03	Irrigated	20-30	6.8	8.1	0.12	8	3.7	0.37	5	30	4.6	1.3	0.6	1.0
MVP5-2.03	Irrigated	50-60	6.7	7.8	0.28	14	4.6	0.48	10	149	5.0	3.0	0.4	2.9
MVP5-2.03	Irrigated	80-90	6.4	7.1	0.47	15	3.4	0.39	7	279	3.8	4.2	0.3	2.8
MVP5	Unirrigated	0-10	4.6	5.5	0.06	2	8.8	0.77	19	17	2.9	0.6	0.2	0.1
MVP5	Unirrigated	20-30	5.3	6.2	0.07	4	3.8	0.39	4	25	3.8	1.4	0.1	0.2
MVP5	Unirrigated	50-60	5.6	6.5	0.10	2	3.2	0.39	3	56	4.2	4.7	0.2	0.8
MVP5	Unirrigated	80-90	5.8	6.8	0.09	10	2.9	0.36	2	45	3.9	5.4	0.2	1.1
MVC5	Unirrigated	0-10	6.2	7.2	0.06	2	9.8	0.73	42	6	5.0	1.1	0.5	0.1
MVC5	Unirrigated	20-30	6.5	7.8	0.07	4	5.9	0.47	12	8	4.0	1.2	0.4	0.5
MVC5	Unirrigated	50-60	6.5	7.6	0.21	3	3.4	0.36	5	108	3.8	3.4	0.3	2.6
MVC5	Unirrigated	80-90	6.7	7.8	0.25	10	2.7	0.32	4	133	3.8	3.7	0.3	2.9
MVP4-2.13	Irrigated	0-10	7.3	8.2	0.14	7	9.8	0.83	50	17	6.0	1.0	0.7	0.6
MVP4-2.13	Irrigated	20-30	6.6	7.9	0.15	14	2.4	0.23	6	56	1.7	0.9	0.3	1.0
MVP4-2.13	Irrigated	50-60	6.5	7.2	0.49	42	2.8	0.34	3	280	4.7	6.5	0.3	2.8
MVP4-2.13	Irrigated	80-90	6.9	7.7	0.47	46	2.9	0.34	4	250	5.5	7.3	0.3	2.6
MVC4-2.15	Unirrigated	0-10	5.9	6.8	0.08	4	8.4	0.60	15	32	5.5	0.8	0.4	0.3
MVC4-2.15	Unirrigated	20-30	6.1	7.1	0.08	6	5.0	0.39	6	33	5.0	1.2	0.3	0.3
MVC4-2.15	Unirrigated	50-60	6.3	7.0	0.24	9	2.5	0.30	3	157	5.1	4.3	0.2	1.3
MVC4-2.15	Unirrigated	80-90	6.3	7.0	0.28	10	3.5	0.38	3	183	5.7	5.1	0.3	1.4

Wheat at Maryvale

Plot	Treatment	Depth (cm)	pH-Ca	pH-W	$EC_{1:5}$ (dS/m)	Extr Cl (mg/kg)	Total C (g/kg)	Total N (g/kg)	Bray-P (mg/kg)	Extr S (mg/kg)	Exch Ca (cmolc/kg)	Exch Mg (cmolc/kg)	Exch K (cmolc/kg)	Exch Na (cmolc/kg)
MVP2a.1	Irrigated	0 - 10	7.6	8.2	0.12	3	11.1	0.91	28	5	7.8	0.9	0.6	0.2
MVP2a.1	Irrigated	20 - 30	7.5	8.3	0.10	6	5.4	0.50	11	9	5.0	0.8	0.6	0.2
MVP2a.1	Irrigated	50 - 60	7.1	8.4	0.18	9	3.5	0.41	4	55	7.6	0.8	0.6	0.1
MVP2a.2	Irrigated	0 - 10	8.1	8.8	0.17	9	9.5	0.70	21	25	7.4	0.9	0.5	0.6
MVP2a.2	Irrigated	20 - 30	8.3	9.1	0.16	11	3.2	0.27	10	32	3.7	0.5	0.2	0.7
MVP2a.2	Irrigated	50 - 60	7.3	8.3	0.33	26	2.2	0.26	4	174	3.8	3.0	0.2	2.9
MVP2b.1	Irrigated	0 - 10	7.4	8.1	0.08	4	9.2	0.82	17	4	6.7	0.7	0.5	0.1
MVP2b.1	Irrigated	20 - 30	7.3	8.1	0.07	1	6.4	0.60	9	5	5.8	0.9	0.5	0.1
MVP2b.1	Irrigated	50 - 60	6.9	8.3	0.16	7	4.8	0.54	3	45	4.5	2.5	0.3	2.9
MVP2b.2	Irrigated	0 - 10	8.0	8.6	0.12	5	8.0	0.59	29	9	6.6	0.8	0.4	0.2
MVP2b.2	Irrigated	20 - 30	8.0	9.1	0.19	10	3.3	0.30	7	27	3.9	1.1	0.3	1.4
MVP2b.2	Irrigated	50 - 60	7.4	8.3	0.68	51	2.4	0.31	2	367	4.3	7.9	0.3	5.9
MVP2c.2	Irrigated	0 - 10	8.0	8.6	0.14	6	7.6	0.62	9	14	6.5	0.9	0.5	0.3
MVP2c.2	Irrigated	20 - 30	7.8	8.8	0.15	13	4.2	0.41	5	22	4.4	0.9	0.5	0.9
MVP2c.2	Irrigated	50 - 60	6.3	7.3	0.30	23	1.8	0.27	2	177	1.8	3.3	0.2	2.9
MVP3a.1	Irrigated	0 - 10	7.5	8.2	0.12	2	14.4	1.16	62	7	9.4	1.2	0.8	0.2
MVP3a.1	Irrigated	20 - 30	7.2	8.2	0.10	5	6.4	0.58	15	11	5.6	1.4	0.6	0.6
MVP3a.1	Irrigated	50 - 60	6.3	7.2	0.26	12	3.0	0.43	3	154	2.8	3.3	0.2	2.3
MVP3a.2	Irrigated	0 - 10	7.5	8.2	0.09	2	8.9	0.77	36	6	5.6	0.6	0.5	0.1
MVP3a.2	Irrigated	20 - 30	7.2	8.2	0.08	4	4.3	0.41	9	8	3.8	0.8	0.5	0.3
MVP3a.2	Irrigated	50 - 60	5.9	6.9	0.19	3	2.7	0.34	3	104	2.0	2.3	0.2	2.5
MVP3b.1	Irrigated	0 - 10	7.6	8.3	0.10	6	11.9	0.92	49	6	6.8	0.7	0.4	0.2
MVP3b.1	Irrigated	20 - 30	7.6	8.6	0.09	8	3.5	0.31	8	14	2.8	0.4	0.2	0.4
MVP3b.1	Irrigated	50 - 60	5.0	5.8	0.30	14	2.3	0.23	3	243	1.6	4.3	0.2	2.5
MVP3b.2	Irrigated	0 - 10	7.8	8.4	0.12	5	7.4	0.47	34	15	6.1	0.8	0.3	0.2
MVP3b.2	Irrigated	20 - 30	7.6	8.8	0.12	5	2.4	0.16	8	23	2.5	0.7	0.2	0.8
MVP3b.2	Irrigated	50 - 60	6.9	8.0	0.23	13	1.5	0.14	2	102	2.5	2.5	0.1	2.1
MVC2a	Unirrigated	0 - 10	6.7	7.3	0.06	7	10.7	0.74	33	10	6.3	0.3	0.2	0.1
MVC2a	Unirrigated	20 - 30	6.1	7.0	0.05	7	5.8	0.35	12	9	4.3	0.7	0.1	0.1
MVC2a	Unirrigated	50 - 60	6.7	7.7	0.14	17	4.1	0.37	3	38	6.3	7.1	0.2	1.6
MVC2b	Unirrigated	0 - 10	5.4	6.3	0.03	0	6.4	0.50	17	4	2.8	0.3	0.1	0.1
MVC2b	Unirrigated	20 - 30	5.3	6.2	0.03	2	3.5	0.25	7	11	2.2	0.5	0.1	0.1
MVC2b	Unirrigated	50 - 60	5.9	6.9	0.08	6	3.3	0.34	3	34	3.2	4.6	0.2	0.8
MVC3a	Unirrigated	0 - 10	5.8	6.7	0.06	9	8.9	0.62	27	9	4.1	0.5	0.2	0.2
MVC3a	Unirrigated	20 - 30	5.7	6.6	0.06	9	5.0	0.38	14	13	2.9	0.4	0.2	0.2
MVC3a	Unirrigated	50 - 60	5.2	6.0	0.08	17	2.4	0.23	2	48	2.3	3.4	0.1	0.6
MVC3b	Unirrigated	0 - 10	5.9	6.7	0.06	3	12.8	0.94	53	4	5.2	0.4	0.2	0.2
MVC3b	Unirrigated	20 - 30	5.4	6.3	0.06	7	6.1	0.42	18	14	3.2	0.4	0.1	0.2
MVC3b	Unirrigated	50 - 60	4.4	5.7	0.07	20	2.7	0.26	2	34	1.3	4.0	0.1	1.0
MVC3c	Unirrigated	0 - 10	5.2	5.9	0.04	1	9.3	0.67	18	5	3.7	0.4	0.1	0.1
MVC3c	Unirrigated	20 - 30	5.2	6.1	0.03	3	3.7	0.30	6	7	2.6	0.7	0.1	0.1
MVC3c	Unirrigated	50 - 60	5.7	6.6	0.04	4	2.7	0.26	2	14	3.2	2.9	0.1	0.2

Wheat, sorghum and pasture at Rosevale

Plot	Treatment	Depth (cm)	pH_{Ca}	pH_{w}	$EC_{1:5}$ (dS/m)	Extr Cl (mg/kg)	Total C (g/kg)	Total N (g/kg)	Bray-P (mg/kg)	Extr S (mg/kg)	Exch Ca (cmolc/kg)	Exch Mg (cmolc/kg)	Exch K (cmolc/kg)	Exch Na (cmolc/kg)
RVP1.1.1	Irrigated	0 - 10	7.9	8.5	0.17	12	9.6	0.71	25	20	6.8	0.8	0.3	0.4
RVP1.1.1	Irrigated	20 - 30	7.4	8.5	0.26	18	5.0	0.39	6	58	5.8	2.8	0.2	2.5
RVP1.1.1	Irrigated	50 - 60	7.3	8.0	0.67	33	5.9	0.50	7	311	6.9	6.7	0.2	3.5
RVP1.1.2	Unirrigated	0 - 10	6.1	6.8	0.05	3	16.1	1.15	36	3	6.6	0.5	0.2	0.1
RVP1.1.2	Unirrigated	20 - 30	5.7	6.5	0.04	3	4.4	0.30	9	8	2.6	0.3	0.1	0.1
RVP1.1.2	Unirrigated	50 - 60	4.8	5.8	0.07	5	4.9	0.40	4	27	4.1	5.4	0.2	0.7
RVP1.2.1	Irrigated	0 - 10	7.5	8.1	0.11	7	12.8	0.96	23	8	8.1	0.8	0.3	0.2
RVP1.2.1	Irrigated	20 - 30	7.1	8.1	0.11	10	4.6	0.31	8	18	3.8	0.8	0.1	0.5
RVP1.2.1	Irrigated	50 - 60	6.3	7.4	0.28	9	6.4	0.54	8	91	3.8	3.8	0.2	3.8
RVP1.2.2	Unirrigated	0 - 10	6.0	6.6	0.08	2	12.6	0.95	40	7	4.8	0.4	0.4	0.1
RVP1.2.2	Unirrigated	20 - 30	5.7	6.4	0.06	5	5.5	0.42	20	6	2.9	0.8	0.2	0.1
RVP1.2.2	Unirrigated	50 - 60	4.9	6.0	0.11	8	6.2	0.50	15	48	3.5	6.2	0.3	0.8
RVP2.1.1	Irrigated	0 - 10	6.8	7.8	0.06	7	7.6	0.54	13	6	4.4	0.6	0.1	0.2
RVP2.1.1	Irrigated	20 - 30	6.8	8.0	0.11	10	3.8	0.30	4	20	4.0	1.3	0.1	1.0
RVP2.1.1	Irrigated	50 - 60	5.7	6.4	0.29	9	4.0	0.37	4	180	3.5	5.1	0.1	2.2
RVP2.1.2	Unirrigated	0 - 10	5.0	5.9	0.04	5	10.8	0.71	15	7	3.0	0.4	0.1	0.1
RVP2.1.2	Unirrigated	20 - 30	5.1	6.4	0.03	5	2.9	0.18	2	6	1.8	2.2	0.1	0.3
RVP2.1.2	Unirrigated	50 - 60	5.7	7.0	0.08	20	3.9	0.31	2	24	2.5	8.1	0.1	1.3

Wheat and pasture at Davey Rd

Plot	Treatment	Depth (cm)	pH_{Ca}	pH_{w}	$EC_{1:5}$ (dS/m)	Extr Cl (mg/kg)	Total C (g/kg)	Total N (g/kg)	Bray-P (mg/kg)	Extr S (mg/kg)	Ex Ca (cmolc/kg)	Ex Mg (cmolc/kg)	Ex K (cmolc/kg)	Ex Na (cmolc/kg)
DRP2.1	Irrigated	0 - 10	6.9	7.8	0.08	4	8.8	0.59	18	5	5.0	0.7	0.5	0.2
DRP2.1	Irrigated	20 - 30	6.3	7.7	0.08	10	4.0	0.27	6	8	2.1	0.8	0.2	0.6
DRP2.1	Irrigated	50 - 60	5.4	6.1	0.28	13	4.5	0.40	9	210	2.6	3.9	0.2	1.8
DRP2.2	Irrigated	0 - 10	6.7	7.7	0.08	8	11.1	0.77	25	9	5.9	0.8	0.5	0.3
DRP2.2	Irrigated	20 - 30	6.7	8.1	0.07	6	4.0	0.27	11	9	2.4	0.5	0.2	0.4
DRP2.2	Irrigated	50 - 60	5.9	6.7	0.24	14	4.1	0.32	4	146	3.9	3.4	0.2	1.6
DRC2	Unirrigated	0 - 10	4.4	5.2	0.05	6	10.4	0.80	31	15	1.7	0.3	0.3	0.1
DRC2	Unirrigated	20 - 30	4.4	5.3	0.05	10	4.7	0.34	12	15	1.4	0.3	0.2	0.1
DRC2	Unirrigated	50 - 60	5.5	6.2	0.07	9	3.6	0.36	3	39	3.8	4.3	0.3	0.6
DRP5a	Irrigated	0 - 10	6.9	7.7	0.10	9	12.0	0.86	39	10	6.3	1.1	0.6	0.3
DRP5a	Irrigated	20 - 30	6.4	7.5	0.16	7	5.1	0.38	7	37	4.6	6.7	0.2	2.1
DRP5a	Irrigated	50 - 60	6.4	7.0	0.41	32	2.8	0.27	2	211	4.2	2.4	0.5	1.6
DRC5a	Unirrigated	0 - 10	4.8	5.5	0.05	6	9.1	0.70	18	7	2.0	0.2	0.2	0.1
DRC5a	Unirrigated	20 - 30	4.5	5.4	0.03	0	2.9	0.21	5	9	1.0	0.2	0.2	0.1
DRC5a	Unirrigated	50 - 60	4.9	5.8	0.07	8	2.5	0.23	2	46	2.6	2.7	0.1	0.4
DRP6b	Irrigated	0 - 10	7.3	8.1	0.13	10	10.8	0.71	32	18	6.0	0.9	0.4	0.4
DRP6b	Irrigated	20 - 30	7.1	8.2	0.17	12	3.5	0.23	5	40	2.7	1.3	0.3	1.3
DRP6b	Irrigated	50 - 60	6.2	6.9	0.58	12	2.8	0.21	4	317	2.8	4.8	0.2	3.6
DRC6b	Unirrigated	0 - 10	4.6	5.3	0.28	72	13.1	1.08	57	52	1.9	0.6	1.4	0.1
DRC6b	Unirrigated	20 - 30	4.5	5.1	0.19	63	5.6	0.44	19	42	1.2	0.5	1.0	0.1
DRC6b	Unirrigated	50 - 60	4.8	5.4	0.19	49	4.4	0.37	6	73	3.6	3.4	1.1	0.4

Appendix 2. Salinity in root zones of trees, crops and pastures in 2012.

Ettamogah Plantation

Site	Soil Unit	Plot	Treatment	Layer (cm)	$EC_{1:5}$ (dS/m)	EC_{se} (dS/m)	WU Factor	WUW EC_{se} (dS/m) Layer	Profile
Ettamogah	Unit 4	1.26	Effluent	0-10	0.092	0.64	0.41	0.26	
Ettamogah	Unit 4	1.26	Effluent	20-30	0.105	0.74	0.21	0.15	
Ettamogah	Unit 4	1.26	Effluent	50-60	0.280	1.96	0.25	0.49	
Ettamogah	Unit 4	1.26	Effluent	80-90	0.383	2.68	0.13	0.35	1.26
Ettamogah	Unit 1	3.02	Effluent	0-10	0.093	0.65	0.41	0.27	
Ettamogah	Unit 1	3.02	Effluent	20-30	0.102	0.71	0.21	0.15	
Ettamogah	Unit 1	3.02	Effluent	50-60	0.381	2.67	0.25	0.67	
Ettamogah	Unit 1	3.02	Effluent	80-90	0.395	2.77	0.13	0.36	1.44
Ettamogah	Unit 2	3.11	Effluent	0-10	0.103	0.72	0.41	0.30	
Ettamogah	Unit 2	3.11	Effluent	20-30	0.121	0.85	0.21	0.18	
Ettamogah	Unit 2	3.11	Effluent	50-60	0.169	1.18	0.25	0.30	
Ettamogah	Unit 2	3.11	Effluent	80-90	0.177	1.24	0.13	0.16	0.93
Ettamogah	Unit 4	3.15	Effluent	0-10	0.040	0.28	0.41	0.11	
Ettamogah	Unit 4	3.15	Effluent	20-30	0.041	0.29	0.21	0.06	
Ettamogah	Unit 4	3.15	Effluent	50-60	0.232	1.62	0.25	0.41	
Ettamogah	Unit 4	3.15	Effluent	80-90	0.546	3.82	0.13	0.50	1.08
								Average	1.18
								Std Dev	0.22
								Covar%	19

Ettamogah and Maryvale Crops and Pasture: Irrigated Plots

Site	Soil Unit	Plot	Treatment	Layer (cm)	$EC_{1:5}$ (dS/m)	EC_{se} (dS/m)	WU Factor	WUW EC_{se} (dS/m) Layer	Profile
Ettamogah	Unit 2	MVP5-2.03	Effluent	0-10	0.090	0.63	0.53	0.33	
Ettamogah	Unit 2	MVP5-2.03	Effluent	20-30	0.117	0.82	0.28	0.23	
Ettamogah	Unit 2	MVP5-2.03	Effluent	50-60	0.285	2.00	0.19	0.38	0.94
Ettamogah	Unit 3	MVP4-2.13	Effluent	0-10	0.136	0.95	0.53	0.50	
Ettamogah	Unit 3	MVP4-2.13	Effluent	20-30	0.145	1.02	0.28	0.28	
Ettamogah	Unit 3	MVP4-2.13	Effluent	50-60	0.491	3.44	0.19	0.65	1.44
Ettamogah	Unit 3	1.03	Effluent	0-10	0.064	0.45	0.53	0.24	
Ettamogah	Unit 3	1.03	Effluent	20-30	0.054	0.38	0.28	0.11	
Ettamogah	Unit 3	1.03	Effluent	50-60	0.216	1.51	0.19	0.29	0.63
Maryvale	Unit 2	MVP2a.1	Effluent	0-10	0.119	0.83	0.53	0.44	
Maryvale	Unit 2	MVP2a.1	Effluent	20-30	0.097	0.68	0.28	0.19	
Maryvale	Unit 2	MVP2a.1	Effluent	50-60	0.183	1.28	0.19	0.24	0.88
Maryvale	Unit 3	MVP2a.2	Effluent	0-10	0.166	1.16	0.53	0.62	
Maryvale	Unit 3	MVP2a.2	Effluent	20-30	0.162	1.13	0.28	0.32	
Maryvale	Unit 3	MVP2a.2	Effluent	50-60	0.326	2.28	0.19	0.43	1.37
Maryvale	Unit 2	MVP2b.1	Effluent	0-10	0.078	0.55	0.53	0.29	
Maryvale	Unit 2	MVP2b.1	Effluent	20-30	0.071	0.50	0.28	0.14	
Maryvale	Unit 2	MVP2b.1	Effluent	50-60	0.161	1.13	0.19	0.21	0.64
Maryvale	Unit 3	MVP2b.2	Effluent	0-10	0.118	0.83	0.53	0.44	
Maryvale	Unit 3	MVP2b.2	Effluent	20-30	0.190	1.33	0.28	0.37	
Maryvale	Unit 3	MVP2b.2	Effluent	50-60	0.682	4.77	0.19	0.91	1.72
Maryvale	Unit 4	MVP2c.2	Effluent	0-10	0.138	0.97	0.53	0.51	
Maryvale	Unit 4	MVP2c.2	Effluent	20-30	0.155	1.09	0.28	0.30	
Maryvale	Unit 4	MVP2c.2	Effluent	50-60	0.302	2.11	0.19	0.40	1.22
Maryvale	Unit 4	MVP3a.1	Effluent	0-10	0.117	0.82	0.53	0.43	
Maryvale	Unit 4	MVP3a.1	Effluent	20-30	0.098	0.69	0.28	0.19	
Maryvale	Unit 4	MVP3a.1	Effluent	50-60	0.261	1.83	0.19	0.35	0.97
Maryvale	Unit 4	MVP3a.2	Effluent	0-10	0.091	0.64	0.53	0.34	
Maryvale	Unit 4	MVP3a.2	Effluent	20-30	0.081	0.57	0.28	0.16	
Maryvale	Unit 4	MVP3a.2	Effluent	50-60	0.194	1.36	0.19	0.26	0.75
Maryvale	Unit 4	MVP3b.1	Effluent	0-10	0.104	0.73	0.53	0.39	
Maryvale	Unit 4	MVP3b.1	Effluent	20-30	0.094	0.66	0.28	0.18	
Maryvale	Unit 4	MVP3b.1	Effluent	50-60	0.302	2.11	0.19	0.40	0.97
Maryvale	Unit 4	MVP3b.2	Effluent	0-10	0.123	0.86	0.53	0.46	
Maryvale	Unit 4	MVP3b.2	Effluent	20-30	0.117	0.82	0.28	0.23	
Maryvale	Unit 4	MVP3b.2	Effluent	50-60	0.227	1.59	0.19	0.30	0.99
								Average	1.04
								Std Dev	0.33
								Covar%	32

Ettamogah and Maryvale Crops and Pasture: Unirrigated Plots

Site	Soil Unit	Plot	Treatment	Layer (cm)	$EC_{1:5}$ (dS/m)	EC_{se} (dS/m)	WU Factor	WUW EC_{se} (dS/m) Layer	Profile
Ettamogah	Unit 3	1.02	Nil	0-10	0.047	0.33	0.53	0.17	
Ettamogah	Unit 3	1.02	Nil	20-30	0.068	0.48	0.28	0.13	
Ettamogah	Unit 3	1.02	Nil	50-60	0.167	1.17	0.19	0.22	0.53
Ettamogah	Unit 1	1.09	Nil	0-10	0.068	0.48	0.53	0.25	
Ettamogah	Unit 1	1.09	Nil	20-30	0.085	0.60	0.28	0.17	
Ettamogah	Unit 1	1.09	Nil	50-60	0.112	0.78	0.19	0.15	0.57
Ettamogah	Unit 2	MVP5	Nil	0-10	0.065	0.46	0.53	0.24	
Ettamogah	Unit 2	MVP5	Nil	20-30	0.071	0.50	0.28	0.14	
Ettamogah	Unit 2	MVP5	Nil	50-60	0.098	0.69	0.19	0.13	0.51
Ettamogah	Unit 2	MVC5	Nil	0-10	0.056	0.39	0.53	0.21	
Ettamogah	Unit 2	MVC5	Nil	20-30	0.070	0.49	0.28	0.14	
Ettamogah	Unit 2	MVC5	Nil	50-60	0.214	1.50	0.19	0.28	0.63
Ettamogah	Unit 4	MVC4-2.15	Nil	0-10	0.085	0.60	0.53	0.32	
Ettamogah	Unit 4	MVC4-2.15	Nil	20-30	0.084	0.59	0.28	0.16	
Ettamogah	Unit 4	MVC4-2.15	Nil	50-60	0.245	1.72	0.19	0.33	0.81
Maryvale	Unit 2	MVC2a	Nil	0-10	0.065	0.46	0.53	0.24	
Maryvale	Unit 2	MVC2a	Nil	20-30	0.049	0.34	0.28	0.10	
Maryvale	Unit 2	MVC2a	Nil	50-60	0.140	0.98	0.19	0.19	0.52
Maryvale	Unit 2	MVC2b	Nil	0-10	0.033	0.23	0.53	0.12	
Maryvale	Unit 2	MVC2b	Nil	20-30	0.034	0.24	0.28	0.07	
Maryvale	Unit 2	MVC2b	Nil	50-60	0.076	0.53	0.19	0.10	0.29
Maryvale	Unit 4	MVC3a	Nil	0-10	0.058	0.41	0.53	0.22	
Maryvale	Unit 4	MVC3a	Nil	20-30	0.059	0.41	0.28	0.12	
Maryvale	Unit 4	MVC3a	Nil	50-60	0.078	0.55	0.19	0.10	0.43
Maryvale	Unit 4	MVC3b	Nil	0-10	0.057	0.40	0.53	0.21	
Maryvale	Unit 4	MVC3b	Nil	20-30	0.058	0.41	0.28	0.11	
Maryvale	Unit 4	MVC3b	Nil	50-60	0.071	0.50	0.19	0.09	0.42
Maryvale	Unit 4	MVC3c	Nil	0-10	0.036	0.25	0.53	0.13	
Maryvale	Unit 4	MVC3c	Nil	20-30	0.030	0.21	0.28	0.06	
Maryvale	Unit 4	MVC3c	Nil	50-60	0.042	0.29	0.19	0.06	0.25
								Average	0.50
								Std Dev	0.16
								Covar%	33

Rosevale Crops and Pasture: Irrigated Plots

Site	Soil Unit	Plot	Treatment	Layer (cm)	$EC_{1:5}$ (dS/m)	EC_{se} (dS/m)	WU Factor	WUW EC_{se} (dS/m) Layer	Profile
Rosevale	Unit 3	RVP1.1.1	Effluent	0-10	0.165	1.16	0.53	0.61	
Rosevale	Unit 3	RVP1.1.1	Effluent	20-30	0.264	1.85	0.28	0.52	
Rosevale	Unit 3	RVP1.1.1	Effluent	50-60	0.673	4.71	0.19	0.90	2.02
Rosevale	Unit 3	RVP1.2.1	Effluent	0-10	0.110	0.77	0.53	0.41	
Rosevale	Unit 3	RVP1.2.1	Effluent	20-30	0.110	0.77	0.28	0.22	
Rosevale	Unit 3	RVP1.2.1	Effluent	50-60	0.277	1.94	0.19	0.37	0.99
Rosevale	Unit 4	RVP2.1.1	Effluent	0-10	0.061	0.43	0.53	0.23	
Rosevale	Unit 4	RVP2.1.1	Effluent	20-30	0.112	0.78	0.28	0.22	
Rosevale	Unit 4	RVP2.1.1	Effluent	50-60	0.291	2.04	0.19	0.39	0.83
								Average	1.28
								Std Dev	0.65
								Covar%	50

Rosevale Crops and Pasture: Unirrigated Plots

Site	Soil Unit	Plot	Treatment	Layer	$EC_{1:5}$ (dS/m)	EC_{se} (dS/m)	WU Factor	WUW EC_{se} (dS/m) Layer	Profile
Rosevale	Unit 3	RVP1.1.2	Nil	0-10	0.052	0.36	0.53	0.19	
Rosevale	Unit 3	RVP1.1.2	Nil	20-30	0.039	0.27	0.28	0.08	
Rosevale	Unit 3	RVP1.1.2	Nil	50-60	0.066	0.46	0.19	0.09	0.36
Rosevale	Unit 3	RVP1.2.2	Nil	0-10	0.082	0.57	0.53	0.30	
Rosevale	Unit 3	RVP1.2.2	Nil	20-30	0.061	0.43	0.28	0.12	
Rosevale	Unit 3	RVP1.2.2	Nil	50-60	0.109	0.76	0.19	0.14	0.57
Rosevale	Unit 4	RVP2.1.2	Nil	0-10	0.038	0.27	0.53	0.14	
Rosevale	Unit 4	RVP2.1.2	Nil	20-30	0.035	0.25	0.28	0.07	
Rosevale	Unit 4	RVP2.1.2	Nil	50-60	0.084	0.59	0.19	0.11	0.32
								Average	0.42
								Std Dev	0.13
								Covar%	32

Davey Rd Crops and Pasture: Irrigated Plots

Site	Soil Unit	Plot	Treatment	Layer	$EC_{1:5}$ (dS/m)	EC_{se} (dS/m)	WU Factor	WUW EC_{se} (dS/m) Layer	Profile
Davey Rd	Unit 2	DRP2.1	Effluent	0-10	0.082	0.57	0.53	0.30	
Davey Rd	Unit 2	DRP2.1	Effluent	20-30	0.080	0.56	0.28	0.16	
Davey Rd	Unit 2	DRP2.1	Effluent	50-60	0.285	2.00	0.19	0.38	0.84
Davey Rd	Unit 2	DRP2.2	Effluent	0-10	0.083	0.58	0.53	0.31	
Davey Rd	Unit 2	DRP2.2	Effluent	20-30	0.070	0.49	0.28	0.14	
Davey Rd	Unit 2	DRP2.2	Effluent	50-60	0.240	1.68	0.19	0.32	0.76
Davey Rd	Unit 3	DRP5a	Effluent	0-10	0.102	0.71	0.53	0.38	
Davey Rd	Unit 3	DRP5a	Effluent	20-30	0.156	1.09	0.28	0.31	
Davey Rd	Unit 3	DRP5a	Effluent	50-60	0.405	2.84	0.19	0.54	1.22
Davey Rd	Unit 3	DRP6b	Effluent	0-10	0.128	0.90	0.53	0.47	
Davey Rd	Unit 3	DRP6b	Effluent	20-30	0.169	1.18	0.28	0.33	
Davey Rd	Unit 3	DRP6b	Effluent	50-60	0.577	4.04	0.19	0.77	1.57
								Average	1.10
								Std Dev	0.37
								Covar%	34

Davey Rd Crops and Pasture: Unirrigated Plots

Site	Soil Unit	Plot	Treatment	Layer	$EC_{1:5}$ (dS/m)	EC_{se} (dS/m)	WU Factor	WUW EC_{se} (dS/m) Layer	Profile
Davey Rd	Unit 2	DRC2	Nil	0-10	0.047	0.33	0.53	0.17	
Davey Rd	Unit 2	DRC2	Nil	20-30	0.045	0.32	0.28	0.09	
Davey Rd	Unit 2	DRC2	Nil	50-60	0.071	0.50	0.19	0.09	0.36
Davey Rd	Unit 3	DRC5a	Nil	0-10	0.048	0.34	0.53	0.18	
Davey Rd	Unit 3	DRC5a	Nil	20-30	0.031	0.22	0.28	0.06	
Davey Rd	Unit 3	DRC5a	Nil	50-60	0.075	0.53	0.19	0.10	0.34
Davey Rd	Unit 3	DRC6b	Nil	0-10	0.285	2.00	0.53	1.06	
Davey Rd	Unit 3	DRC6b	Nil	20-30	0.194	1.36	0.28	0.38	
Davey Rd	Unit 3	DRC6b	Nil	50-60	0.189	1.32	0.19	0.25	1.69
								Average	0.79
								Std Dev	0.77
								Covar%	97

Appendix 3. Annual rainfall, pan evaporation, irrigation and loads of nitrogen, phosphorus, zinc and total dissolved solids (TDS) in effluent applied from 1st July 2011 to 30th June 2012 to tree plantations, crops and pastures.

Irrigation year 1 July - 30 June	Rainfall (mm)	Evaporation (mm)	Rainfall (ML/ha)	Irrigation: trees (ML/ha)	Total hydraulic load: trees (ML/ha)	Irrigation: pasture (ML/ha)	Total hydraulic load: pasture (ML/ha)	N trees (kg/ha)	N pasture	P trees (kg/ha)	P pasture	Zn trees (kg/ha)	Zn pasture	TDS trees (kg/ha)	TDS pasture
2011 - 2012	943	1232	9.4	4.5	13.9	2.2	11.6	14.4	7.0	1.4	0.71	0.13	0.07	5075	2628

Appendix 4. Aggregate stability and clay dispersion of soils of irrigated tree plantations at Ettamogah and crops and pastures at Ettamogah, Maryvale, Rosevale and Davey Rd in 2012.

Tree plantations at Ettamogah

Plot	Soil	Treatment	Depth	Slaking Water	Dispersion# Dry Water 2hr / 20hr	Dispersion Remoulded Water 2hr / 20hr	Emerson Class Water	Slaking Effluent	Dispersion Dry Effluent 2hr / 20hr	Dispersion Remoulded Effluent 2hr / 20hr	Emerson Class Effluent
1.26	Unit 4	Irrigated	0-10	Considerable	N N	M M	3b	Considerable	N N	N N	6
1.26	Unit 4	Irrigated	20-30	Considerable	N S	ST ST	3a	Considerable	N N	N N	6
1.26	Unit 4	Irrigated	50-60	Considerable	ST C	C C	1	Considerable	N N	N N	6
1.26	Unit 4	Irrigated	80-90	Considerable	ST C	M M	1	Considerable	N N	N N	6
3.02	Unit 1	Irrigated	0-10	Considerable	N N	S M	3b	Considerable	N N	N N	5
3.02	Unit 1	Irrigated	20-30	Considerable	N N	M M	3b	Considerable	N N	N N	6
3.02	Unit 1	Irrigated	50-60	Considerable	N N	N N	5	Considerable	N N	N N	6
3.02	Unit 1	Irrigated	80-90	Considerable	N N	N N	5	Considerable	N N	N N	6
3.11	Unit 2	Irrigated	0-10	Considerable	N N	M M	3b	Considerable	N N	N N	6
3.11	Unit 2	Irrigated	20-30	Considerable	N N	N N	5	Considerable	N N	N N	6
3.11	Unit 2	Irrigated	50-60	Considerable	N N	N N	5	Considerable	N N	N N	6
3.11	Unit 2	Irrigated	80-90	Considerable	N N	N N	5	Considerable	N N	N N	6
3.15	Unit 4	Irrigated	0-10	Considerable	N N	S M	3b	Considerable	N N	N N	6
3.15	Unit 4	Irrigated	20-30	Considerable	S S	S M	3b	Considerable	N N	N N	6
3.15	Unit 4	Irrigated	50-60	Considerable	S M	M M	2	Considerable	N N	N N	6
3.15	Unit 4	Irrigated	80-90	Considerable	N N	N N	6	Considerable	N N	N N	6

Dispersion Classes: N (nil), S (slight), M (moderate), ST (strong), C (complete)

Crops and pasture at Ettamogah

Plot	Soil	Treatment	Depth	Slaking Water	Dispersion[#] Dry Water 2hr / 20hr	Dispersion Remoulded Water 2hr / 20hr	Emerson Class Water	Slaking Effluent	Dispersion Dry Effluent 2hr / 20hr	Dispersion Remoulded Effluent 2hr / 20hr	Emerson Class Effluent
1.02	Unit 3	Unirrigated	0-10	Considerable	N N	S S	3b	Considerable	N N	N N	5
1.02	Unit 3	Unirrigated	20-30	Considerable	N N	C C	3a	Considerable	N N	N N	5
1.02	Unit 3	Unirrigated	50-60	Considerable	M ST	ST ST	1	Considerable	N N	N N	6
1.02	Unit 3	Unirrigated	80-90	Considerable	ST ST	S S	1	Considerable	N N	N N	6
1.03	Unit 3	Irrigated	0-10	Considerable	N N	ST ST	3a	Considerable	N N	N N	5
1.03	Unit 3	Irrigated	20-30	Considerable	N M	ST ST	3a	Considerable	N N	N N	5
1.03	Unit 3	Irrigated	50-60	Considerable	ST ST	ST C	2	Considerable	N N	N N	6
1.03	Unit 3	Irrigated	80-90	Considerable	M C	M M	2	Considerable	N N	N N	6
1.09	Unit 1	Unirrigated	0-10	Considerable	N N	N S	5	Considerable	N N	N N	5
1.09	Unit 1	Unirrigated	20-30	Considerable	N N	N N	5	Considerable	N N	N N	5
1.09	Unit 1	Unirrigated	50-60	Considerable	N S	S M	3b	Considerable	N N	N N	6
1.09	Unit 1	Unirrigated	80-90	Considerable	N N	S M	3b	Considerable	N N	N N	6
MVP5-2.03	Unit 2	Irrigated	0-10	Considerable	N N	S M	3b	Considerable	N N	N N	5
MVP5-2.03	Unit 2	Irrigated	20-30	Considerable	S M	ST C	2	Considerable	N N	N N	6
MVP5-2.03	Unit 2	Irrigated	50-60	Considerable	S M	S S	2	Considerable	N N	N N	6
MVP5-2.03	Unit 2	Irrigated	80-90	Considerable	N S	N N	6	Considerable	N N	N N	6
MVP5	Unit 2	Unirrigated	0-10	Considerable	N N	N N	5	Considerable	N N	N N	5
MVP5	Unit 2	Unirrigated	20-30	Considerable	S S	N N	5	Considerable	N N	N N	6
MVP5	Unit 2	Unirrigated	50-60	Considerable	N N	N N	5	Considerable	N N	N N	6
MVP5	Unit 2	Unirrigated	80-90	Considerable	N N	N N	5	Considerable	N N	N N	6
MVC5	Unit 4	Unirrigated	0-10	Considerable	N N	S M	3a	Considerable	N N	N N	6
MVC5	Unit 4	Unirrigated	20-30	Considerable	N S	ST ST	3a	Considerable	N N	N N	6
MVC5	Unit 4	Unirrigated	50-60	Considerable	S M	S S	2	Considerable	N N	N N	6
MVC5	Unit 4	Unirrigated	80-90	Considerable	S S	N N	2	Considerable	N N	N N	6
MVP4-2.13	Unit 3	Irrigated	0-10	Considerable	N S	ST ST	3a	Considerable	N N	N N	5
MVP4-2.13	Unit 3	Irrigated	20-30	Considerable	S M	C C	1	Considerable	N N	N N	6
MVP4-2.13	Unit 3	Irrigated	50-60	Considerable	S S	N N	2	Considerable	N N	N N	6
MVP4-2.13	Unit 3	Irrigated	80-90	Considerable	N S	N S	5	Considerable	N N	N N	6
MVC4-2.15	Unit 4	Unirrigated	0-10	Considerable	N S	N S	5	Considerable	N N	N N	5
MVC4-2.15	Unit 4	Unirrigated	20-30	Considerable	N N	N N	5	Considerable	N N	N N	6
MVC4-2.15	Unit 4	Unirrigated	50-60	Considerable	N N	N N	5	Considerable	N N	N N	6
MVC4-2.15	Unit 4	Unirrigated	80-90	Considerable	N N	N N	5	Considerable	N N	N N	6

[#] Dispersion Classes: N (nil), S (slight), M (moderate), ST (strong), C (complete)

Crops and pasture at Maryvale

Plot	Soil	Treatment	Depth	Slaking Water	Dispersion Dry Water 2hr / 20hr	Dispersion Remoulded Water 2hr / 20hr	Emerson Class Water	Slaking Effluent	Dispersion Dry Effluent 2hr / 20hr	Dispersion Remoulded Effluent 2hr / 20hr	Emerson Class Effluent
MVP2a.1	Unit 2	Irrigated	0-10	Considerable	N N	N S	3b	Considerable	N N	N N	6
MVP2a.1	Unit 2	Irrigated	20-30	Considerable	N S	M M	3b	Considerable	N N	N N	6
MVP2a.1	Unit 2	Irrigated	50-60	Considerable	M C	ST C	1	Considerable	N N	N N	6
MVP2a.2	Unit 3	Irrigated	0-10	Considerable	N N	M M	3b	Considerable	N N	N N	6
MVP2a.2	Unit 3	Irrigated	20-30	Considerable	S S	M M	3b	Considerable	N N	N N	6
MVP2a.2	Unit 3	Irrigated	50-60	Considerable	M ST	ST ST	1	Considerable	N N	N N	6
MVP2b.1	Unit 2	Irrigated	0-10	Considerable	N N	S S	3b	Considerable	N N	N N	5
MVP2b.1	Unit 2	Irrigated	20-30	Considerable	N N	N S	5	Considerable	N N	N N	6
MVP2b.1	Unit 2	Irrigated	50-60	Considerable	S M	M M	2	Considerable	N N	N N	6
MVP2b.2	Unit 3	Irrigated	0-10	Considerable	N N	S S	3b	Considerable	N N	N N	6
MVP2b.2	Unit 3	Irrigated	20-30	Considerable	ST ST	ST ST	1	Considerable	N N	N N	6
MVP2b.2	Unit 3	Irrigated	50-60	Considerable	ST ST	M M	1	Considerable	N N	N N	6
MVP2c.2	Unit 4	Irrigated	0-10	Considerable	N N	S M	3b	Considerable	N N	N N	6
MVP2c.2	Unit 4	Irrigated	20-30	Considerable	S M	C C	2	Considerable	N N	N N	6
MVP2c.2	Unit 4	Irrigated	50-60	Considerable	M ST	N N	1	Considerable	N N	N N	6
MVP3a.1	Unit 4	Irrigated	0-10	Considerable	N N	S M	3b	Considerable	N N	N N	6
MVP3a.1	Unit 4	Irrigated	20-30	Considerable	S M	ST ST	2	Considerable	N N	N N	6
MVP3a.1	Unit 4	Irrigated	50-60	Considerable	N S	N N	6	Considerable	N N	N N	6
MVP3a.2	Unit 4	Irrigated	0-10	Considerable	N N	S M	3b	Considerable	N N	N N	5
MVP3a.2	Unit 4	Irrigated	20-30	Considerable	N S	M ST	3a	Considerable	N N	N N	6
MVP3a.2	Unit 4	Irrigated	50-60	Considerable	M M	N N	2	Considerable	N N	N N	6
MVP3b.1	Unit 4	Irrigated	0-10	Considerable	N N	M M	3b	Considerable	N N	N N	5
MVP3b.1	Unit 4	Irrigated	20-30	Considerable	M M	M M	2	Considerable	N N	N N	6
MVP3b.1	Unit 4	Irrigated	50-60	Considerable	S S	N N	2	Considerable	N N	N N	6
MVP3b.2	Unit 4	Irrigated	0-10	Considerable	N N	S S	3a	Considerable	N N	N N	5
MVP3b.2	Unit 4	Irrigated	20-30	Considerable	S M	ST ST	2	Considerable	N N	N N	6
MVP3b.2	Unit 4	Irrigated	50-60	Considerable	ST C	M ST	1	Considerable	N N	N N	6
MVC2a	Unit 2	Unirrigated	0-10	Considerable	N N	S S	3b	Considerable	N N	N N	5
MVC2a	Unit 2	Unirrigated	20-30	Considerable	N N	N S	3b	Considerable	N N	N N	5
MVC2a	Unit 2	Unirrigated	50-60	Considerable	N N	N N	6	Considerable	N N	N N	6
MVC2b	Unit 2	Unirrigated	0-10	Considerable	N N	S S	3b	Considerable	N N	N N	5
MVC2b	Unit 2	Unirrigated	20-30	Considerable	N N	N N	5	Considerable	N N	N N	6
MVC2b	Unit 2	Unirrigated	50-60	Considerable	N N	N N	5	Considerable	N N	N N	6
MVC3a	Unit 4	Unirrigated	0-10	Considerable	N N	S M	3b	Considerable	N N	N N	5
MVC3a	Unit 4	Unirrigated	20-30	Considerable	N N	S M	3b	Considerable	N N	N N	6
MVC3a	Unit 4	Unirrigated	50-60	Considerable	N N	N N	5	Considerable	N N	N N	6
MVC3b	Unit 4	Unirrigated	0-10	Considerable	N N	M M	3b	Considerable	N N	N N	5
MVC3b	Unit 4	Unirrigated	20-30	Considerable	N N	N S	3b	Considerable	N N	N N	5
MVC3b	Unit 4	Unirrigated	50-60	Considerable	N N	N N	5	Considerable	N N	N N	6
MVC3b	Unit 4	Unirrigated	0-10	Considerable	N N	S S	3b	Considerable	N N	N N	5
MVC3b	Unit 4	Unirrigated	20-30	Considerable	N N	N N	5	Considerable	N N	N N	6
MVC3b	Unit 4	Unirrigated	50-60	Considerable	N N	N N	5	Considerable	N N	N N	6

Crops and pasture at Rosevale

Plot	Soil	Treatment	Depth	Slaking Water	Dispersion[#] Dry Water 2hr / 20hr	Dispersion Remoulded Water 2hr / 20hr	Emerson Class Water	Slaking Effluent	Dispersion Dry Effluent 2hr / 20hr	Dispersion Remoulded Effluent 2hr / 20hr	Emerson Class Effluent
RVP1.1.1	Unit 3	Irrigated	0-10	Considerable	N N	S M	3b	Considerable	N N	N N	5
RVP1.1.1	Unit 3	Irrigated	20-30	Considerable	ST ST	C C	1	Considerable	N N	N N	6
RVP1.1.1	Unit 3	Irrigated	50-60	Considerable	N N	S S	3b	Considerable	N N	N N	6
RVP1.1.2	Unit 3	Unirrigated	0-10	Considerable	N N	S S	3b	Considerable	N N	N N	5
RVP1.1.2	Unit 3	Unirrigated	20-30	Considerable	N N	S S	3b	Considerable	N N	N N	5
RVP1.1.2	Unit 3	Unirrigated	50-60	Considerable	N N	N N	5	Considerable	N N	N N	6
RVP1.2.1	Unit 3	Irrigated	0-10	Considerable	N N	M M	3b	Considerable	N N	N N	5
RVP1.2.1	Unit 3	Irrigated	20-30	Considerable	N S	M M	3b	Considerable	N N	N N	6
RVP1.2.1	Unit 3	Irrigated	50-60	Considerable	ST C	ST C	1	Considerable	N N	N N	6
RVP1.2.2	Unit 3	Unirrigated	0-10	Considerable	N N	S S	3b	Considerable	N N	N N	5
RVP1.2.2	Unit 3	Unirrigated	20-30	Considerable	N N	S S	3b	Considerable	N N	N N	5
RVP1.2.2	Unit 3	Unirrigated	50-60	Considerable	N N	N N	6	Considerable	N N	N N	6
RVP2.1.1	Unit 4	Irrigated	0-10	Considerable	N N	S S	3b	Considerable	N N	N N	5
RVP2.1.1	Unit 4	Irrigated	20-30	Considerable	M ST	ST ST	1	Considerable	N N	N N	5
RVP2.1.1	Unit 4	Irrigated	50-60	Considerable	N S	N N	6	Considerable	N N	N N	6
RVP2.1.2	Unit 4	Unirrigated	0-10	Considerable	N N	S S	3b	Considerable	N N	N N	5
RVP2.1.2	Unit 4	Unirrigated	20-30	Considerable	S S	S M	3b	Considerable	N N	N N	6
RVP2.1.2	Unit 4	Unirrigated	50-60	Considerable	N N	S M	3b	Considerable	N N	N N	6

[#] Dispersion Classes: N (nil), S (slight), M (moderate), ST (strong), C (complete)

Crops and pasture at Davey Rd

Plot	Soil	Treatment	Depth	Slaking Water	Dispersion# Dry Water 2hr / 20hr	Dispersion Remoulded Water 2hr / 20hr	Emerson Class Water	Slaking Effluent	Dispersion Dry Effluent 2hr / 20hr	Dispersion Remoulded Effluent 2hr / 20hr	Emerson Class Effluent
DRP2.1	Unit 2	Irrigated	0-10	Considerable	N N	M M	3b	Considerable	N N	N N	5
DRP2.1	Unit 2	Irrigated	20-30	Considerable	M M	C C	2	Considerable	N N	N N	6
DRP2.1	Unit 2	Irrigated	50-60	Considerable	N N	N N	6	Considerable	N N	N N	6
DRP2.2	Unit 2	Irrigated	0-10	Considerable	N N	M M	3b	Considerable	N N	N N	5
DRP2.2	Unit 2	Irrigated	20-30	Considerable	S S	ST ST	3a	Considerable	N N	N N	6
DRP2.2	Unit 2	Irrigated	50-60	Considerable	S M	N N	2	Considerable	N N	N N	6
DRC2	Unit 2	Unirrigated	0-10	Considerable	N N	S M	3b	Considerable	N N	N N	5
DRC2	Unit 2	Unirrigated	20-30	Considerable	S S	N N	5	Considerable	N N	N N	6
DRC2	Unit 2	Unirrigated	50-60	Considerable	N N	N N	5	Considerable	N N	N N	6
DRP5a	Unit 3	Irrigated	0-10	Considerable	N N	M M	3b	Considerable	N N	N N	5
DRP5a	Unit 3	Irrigated	20-30	Considerable	ST ST	C C	1	Considerable	N N	N N	6
DRP5a	Unit 3	Irrigated	50-60	Considerable	N N	N N	6	Considerable	N N	N N	6
DRC5a	Unit 3	Unirrigated	0-10	Considerable	N N	M M	3b	Considerable	N N	N N	5
DRC5a	Unit 3	Unirrigated	20-30	Considerable	S S	S S	3b	Considerable	N N	N N	6
DRC5a	Unit 3	Unirrigated	50-60	Considerable	N N	N N	5	Considerable	N N	N N	6
DRP6b	Unit 3	Irrigated	0-10	Considerable	N N	S M	3b	Considerable	N N	N N	5
DRP6b	Unit 3	Irrigated	20-30	Considerable	M ST	ST ST	1	Considerable	N N	N N	6
DRP6b	Unit 3	Irrigated	50-60	Considerable	ST ST	ST C	1	Considerable	N N	N N	6
DRC6b	Unit 3	Unirrigated	0-10	Considerable	N N	M M	3b	Considerable	N N	N N	5
DRC6b	Unit 3	Unirrigated	20-30	Considerable	N N	S M	3b	Considerable	N N	N N	5
DRC6b	Unit 3	Unirrigated	50-60	Considerable	N N	N N	5	Considerable	N N	N N	6

Dispersion Classes: N (nil), S (slight), M (moderate), ST (strong), C (complete)