Salt-affected soils of south-west Australia: implications for deep drainage

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Introduction

Secondary salinity already covers about 10 % of the Western Australian (WA) wheatbelt, and could reach 23 % if action is not taken to arrest its spread (McFarlane et al., 2004). Engineering solutions such as deep drainage are under consideration for rehabilitation of a range of salt- and waterlogging affected soils (Dogramaci and Degens, 2003). Underlying the installation of deep drainage is the assumption that damage to salinised, waterlogged soils is largely reversible when water tables are lowered. The recovery of the costs of drainage depend on being able to improve soil productivity and generate increased income from the drained land. Alternatively, for natural resources managers, the justification for a deep drain may be to allow the restoration of the vegetation communities that existed on the site prior to salinisation. Productivity on salinised soils may also be achieved by planting of saltland pastures using halophytic species. This strategy has been shown to decrease water tables (Barrett-Lennard and Malcolm, 2003), but effects on recovery of soil properties has not been investigated.

Given the diverse nature of soils and climatic zones subject to salinity and waterlogging in south-west WA, the expected responses in soil productivity to drainage will vary. The texture, structure, and sodicity of the profile will be significant in determining how easily entrained salt is leached. Recovery of soil structure and soil organic matter levels will also have a significant bearing on soil productivity after draining. This paper reviews the properties of naturally saline soils, and of soils that have experienced secondary salinisation and waterlogging. In the full paper, data is also presented on soils before and after deep drains were installed. It also highlights crop productivity after deep drainage, and the value of treatments to accelerate the return of soil productivity to acceptable levels for sustainable and profitable land use after draining.

Properties of salinised soils

Naturally saline soils occur in southwest WA (McArthur, 1991), but they have not been studied in detail presumably because of their low agricultural potential. Such naturally occurring saline soils typically developed on lacustrine sediments around salt lake systems under the influence of saline water discharge. McArthur (1991) describes 6 profiles of naturally saline soils. These soils while not highly saline in the surface layers, become increasingly saline with depth. However, the level of salinity even at depth would not be severely limiting to plant growth. Profiles are neutral to alkaline at the surface but strongly alkaline at depth. Clay in the surface layers varies between 12 and 16 % but increases with depth to over 35 %. Cation exchange capacity was high (> 15 cmol/kg). In surface layers, Ca was the dominant cation, but with depth Mg and Na became more dominant. Naturally occurring salines soils were not sodic in the surface layer, but strongly sodic (> 20 % ESP) at 30 cm and deeper. In their natural state, these soils may suffer from what is termed 'transient salinity" (Rengasamy 2002). Transient salinity arises where there is no shallow water table causing saline discharge to the soil profile. Rather the level of salts in the sub-soil is sufficiently high that salts rise into the root zone during the dry season, but leach out of the surface layers during the passage of the rainy season. The sodicity and clay content of the sub-soil, coupled with low annual rainfall maintain levels of sub-soil salts.

Of particular interest are those soils that occur in broad valleys that have become salinised over time or are at risk of becoming saline. Such salinised soils typically developed on alluvial and lacustrine sediments along drainage lines and around salt lake systems under the influence of rising saline groundwater. Sodic soils are very prevalent in the broad valleys of the WA wheatbelt, and are well represented in the Reference soil profiles described by McArthur (1991).

The surface pH of the salinised or potentially saline soils varies from moderately acid to alkaline but the sub-soils were generally neutral to strongly alkaline. However, not all potentially saline soils are alkaline throughout their sub-soils. Grey clay from alluvial plains east of Katanning (KTO2- McArthur, 1991) was strongly acid (pH H2O < 5.2) below 20 cm depth. Calcium carbonate levels in these soils were generally lower than for the naturally saline soils with none of the reported values > 8 %. Topsoil ECe values were low, but increased with depth except in a Hypocalcic Calcarosol from Beacon. Texture at the soil surface varied from sand in the Yellow Duplex to clay in the Grey Clay. Profiles varied from uniform loam in the case of a Brown Calcarosol to uniform clay in the Grey Clay, but most profiles had a distinct increase in clay levels with depth. Exchangeable Na levels varied in the topsoil, but were generally high in the sub-soil. Generally, the ESP increased with depth and all sub-soils were strongly sodic (ESP > 6 %). However, only the soils with clay textures at the surface had sodic surface horizons. Exchangeable Mg levels were generally high, and often it was the most prevalent cation. Exchangeable Ca generally declined with depth except on the Yellow Duplex soils. Organic matter levels in the soils were low except for the topsoil of the Brown Calcareous soil.

Typically water tables are within 2 m of the soil surface in salinised soils (Moore 1998). Ali et al. (2004) report that salinised soils at Narembeen had water tables at 0-1.5 m depth. Across valley sites at Beacon, Beynon Rd, Morowa Pithara, and Wallatin creek (where deep drains were later installed), water levels ranged from 0 to 1.4 m depth (N. Cox, personal communication).

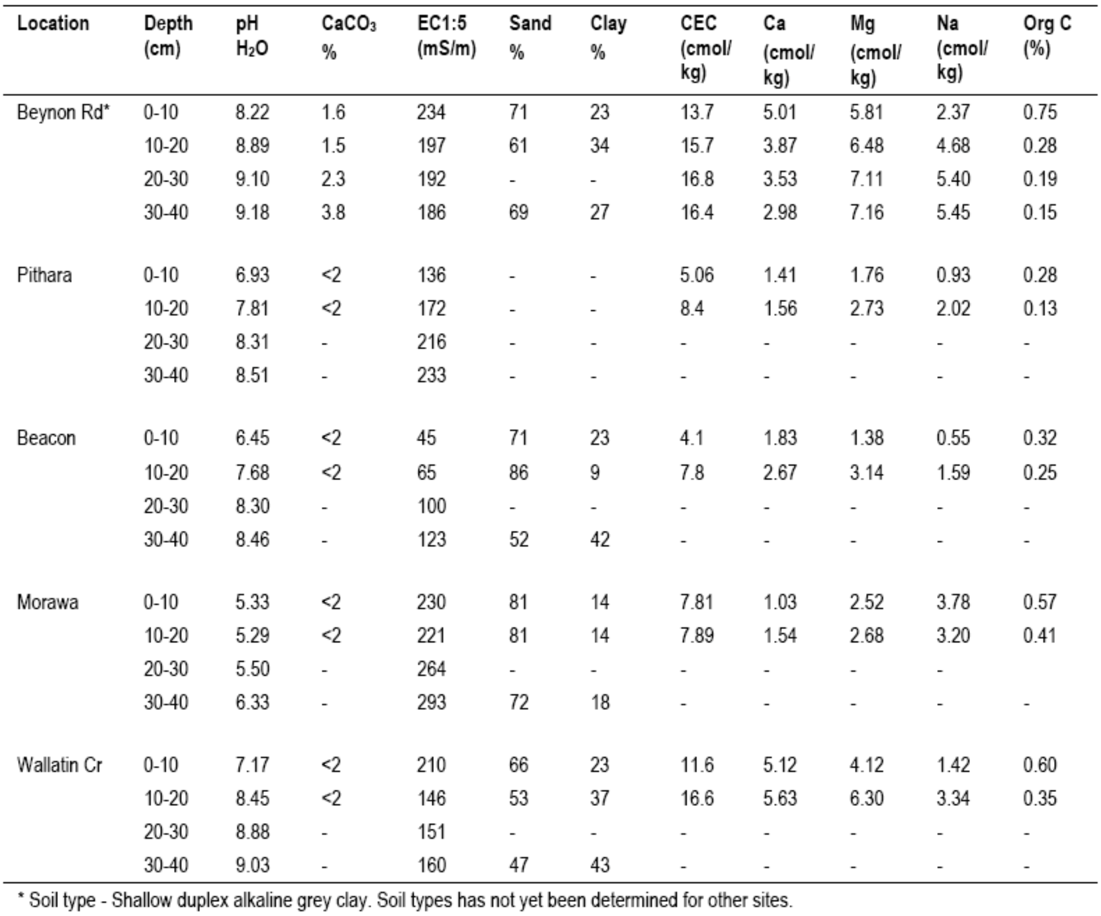
Salinised soils often have low biological productivity and usually increased risk of erosion of bare topsoil (Malcolm, 1983). Erosion would also expose the underlying layers of soil at the surface. These layers often have greater sodicity and potential for dispersion. Hence the eroded soil will have a poorer surface for water infiltration, be more prone to soil loss by dispersion, and form a poor seedbed for plant establishment.

Five salinised soil profiles have been examined in detail from the location of deep drains in the WA wheatbelt (Table 1). Apart from the Beynon Rd samples, all the others represent baseline profile data from immediately before the installation of the deep drain. The Beynon Rd samples were collected in May 2004, about 18 months after the deep drain was installed. Considerable variation is evident in these soil profiles. The most saline soils, based on surface layer EC, were those at Beynon Rd, Morowa and Wallatin creek, all of which had values > 200 mS/m. Sub-soil EC was slightly lower in the Beynon rd and Wallatin creek soils, and slightly higher in Morawa. The lowest EC was in the Beacon soil, which was only marginally saline at the surface (45 mS/m), reflecting the fact that salinity had only become obvious in crop production at that site 2-3 years earlier (G. Kirby, personal communication). By contrast, the Beynon Rd soil had expressed surface salinity for many years (D. Williams, personal communication). Only the Beynon Rd soil was alkaline in the surface layer, but all were alkaline to strongly alkaline at > 20-30 cm except the Morowa soil which varied from pH 5.3 at the surface to 6.3 at 30-40 cm. Only small amounts of CaCO3 were detected in the surface 20 cm of the soils, but no analysis was conducted on the deeper, more alkaline horizons. The Morowa soil had a uniform sandy loam texture to 40 cm depth whereas the other soils had marked increases in clay below 10 or 20 cm depth. Cation exchange capacity was moderate to high at Beynon Rd and Wallatin creek, but low to moderate in the other soils. All soils were sodic in the upper 40 cm of the profile, including the surface layer. The Morowa soil was strongly sodic at the surface (>40 %). Moreover, exchangeable Mg was generally in equal or greater levels than exchangeable Ca. All of the soils from the sites of deep drains had very low levels of organic C.

Conclusions

There is limited knowledge of the soil chemical, physical and biological properties of soils of southwest Australia after they have been subjected to periods of waterlogging and secondary salinisation. Whilst the increase in salinity levels of such soils is well documented, other changes in soils properties that may hinder the recovery of soil productivity following treatments to lower water tables are less well understood. It is not clear how easily reversed such changes in soil properties might be, but rainfall, soil texture and sodicity are likely to be key factors governing the rate of soil recovery. Poor soil structure, and potential dispersiveness may require treatment to achieve recovery of soil productivity in a reasonable time frame after drainage. The effectiveness and cost-benefits of such interventions will need to be determined.

Table 1 Properties of saline soils at sites of deep drains in western Australia. Values represent soil properties before the installation of the deep drain apart from Beynon Rd profiles which were sampled 18 months after installation of the drain.



Location	Depth (cm)	pH H_2O	$CaCO_3$ %	EC1:5 (mS/m)	Sand %	Clay %	CEC (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	Na (cmol/kg)	Org C (%)
Beynon Rd*	0-10	8.22	1.6	234	71	23	13.7	5.01	5.81	2.37	0.75
	10-20	8.89	1.5	197	61	34	15.7	3.87	6.48	4.68	0.28
	20-30	9.10	2.3	192	-	-	16.8	3.53	7.11	5.40	0.19
	30-40	9.18	3.8	186	69	27	16.4	2.98	7.16	5.45	0.15
Pithara	0-10	6.93	<2	136	-	-	5.06	1.41	1.76	0.93	0.28
	10-20	7.81	<2	172	-	-	8.4	1.56	2.73	2.02	0.13
	20-30	8.31	-	216	-	-	-	-	-	-	-
	30-40	8.51	-	233	-	-	-	-	-	-	-
Beacon	0-10	6.45	<2	45	71	23	4.1	1.83	1.38	0.55	0.32
	10-20	7.68	<2	65	86	9	7.8	2.67	3.14	1.59	0.25
	20-30	8.30	-	100	-	-	-	-	-	-	-
	30-40	8.46	-	123	52	42	-	-	-	-	-
Morawa	0-10	5.33	<2	230	81	14	7.81	1.03	2.52	3.78	0.57
	10-20	5.29	<2	221	81	14	7.89	1.54	2.68	3.20	0.41
	20-30	5.50	-	264	-	-	-	-	-	-	
	30-40	6.33	-	293	72	18	-	-	-	-	-
Wallatin Cr	0-10	7.17	<2	210	66	23	11.6	5.12	4.12	1.42	0.60
	10-20	8.45	<2	146	53	37	16.6	5.63	6.30	3.34	0.35
	20-30	8.88	-	151	-	-	-	-	-	-	-
	30-40	9.03	-	160	47	43	-	-	-	-	-

* Soil type - Shallow duplex alkaline grey clay. Soil types has not yet been determined for other sites.

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