Classifying sodic soils: A comparison of the World Reference Base for Soil Resources and Australian Soil Classification systems

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Abstract
In this preliminary study, the World Reference Base (WRB) soil classification system is compared with the Australian Soil Classification (ASC) in order to establish the applicability of the former to Australian soils. Various differences in the structure of the two schemes using sodium-affected soils which cover much of Victoria indicate variation in profile classification and concomitant implications for mapping. Potential modifications to enhance both systems and facilitate the translation of data for mapping are suggested.

Key Words
Soil sodicity, Soil types, Sodosol, Solonetz, Planosol.

Introduction
The World Reference Base for Soil Resources (IUSS Working Group WRB 2007) is considered to be the international standard for describing soil types. Australian soils have been classified according to a number of schemes with the latest being the Australian Soil Classification (ASC) (Isbell 2002). The aim of this preliminary comparison is to gain an understanding as to how readily the world standard can be applied in Australia using sodium-affected soils as a case study. Sodic soils cover a substantial area of the continent with all states and territories being affected (Figure 1), and are frequently found in dryland environments (≤ 500 mm average annual rainfall). Generally speaking, the properties of these soils (e.g. low fertility and clay dispersion) make them difficult to manage, especially with constraints to plant growth and susceptibility to various forms of water erosion. Sodic soils cover approximately 59 % of Victoria (Figure 2) and at least 73 % of the State's agricultural land (Ford *et al*. 1993).

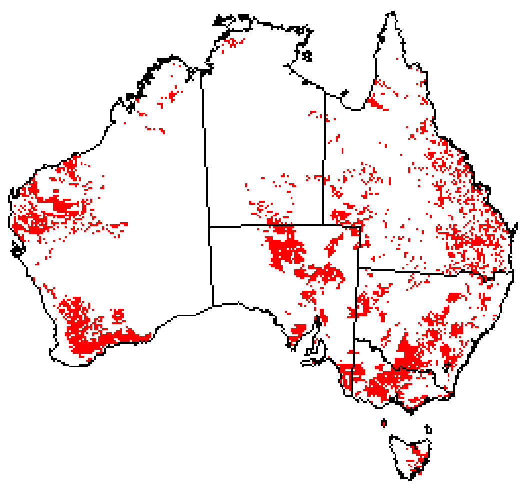

Figure 1. Generalised distribution of Sodosols in Australia (Isbell 2002).

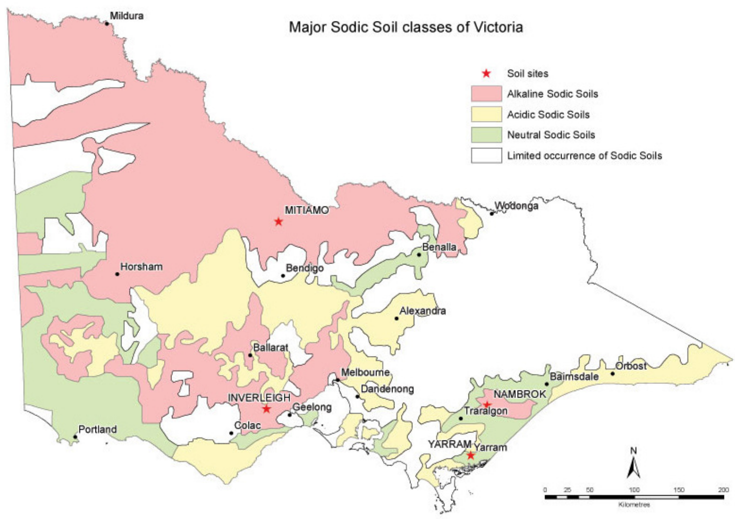

Figure 2. Major sodic soil classes of Victoria (after Ford *et al*. 1993).

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Methods

A comparison of each scheme as it applies to soil sodicity was made in relation to the following factors:

1. Purpose

The ASC was designed to cater for Australia's diversity of soil types while the WRB was intended to be a soil classification framework in which national classifications would fit and, by necessity, has a wide range of criteria to account for international diversity.

2. Structure of the systems

Sodic soils are dominated by a specific Soil Order in each classification; Sodosols in the ASC and Solonetz in the WRB, and the genesis of both terms relating to Australian sodic soils was summarised by Isbell (1995). The term 'Solonetz' has been used in earlier Australian schemes with a specific reference to texture contrast soils comprising columnar-structured clay subsoils (Isbell 1995), although the Order has been defined in broader terms in the WRB. The importance of sodium-affected soils in each classification is indicated by the fact that there are nine Soil Orders in the WRB and seven in the ASC which have a sodic component (Table 1). In the decision matrix, the Solonetz is encountered considerably earlier (indicating a higher relative importance) than Sodosols in the ASC.

Table 1. World Reference Base (WRB) and nominal relationships with the ASC for soils with sodic attributes.

WRB No.	WRB Order	Rationale	ASC No.	ASC Order
6	Vertisol	Water; wet/dry, shrink swell	4	Vertosol (VE)
8	Solonetz	Alkaline	7, 8	Sodosols (SO), Chromosols (CH)
9	Solonchaks	Salty after evaporation	7	Sodosols
10	Gleysols	Groundwater affected	5	Hydrosols (HY)
16	Planosols	Stagnant water, texture contrast	8, 7	Chromosols, Sodosols
17	Stagnosols	Stagnant water, structural or moderate textual discontinuity	7	non-Red Sodosols
23	Calcisols	Accumulation of calcium carbonate	9	Calcarosols (CA)
27	Luvisols	Clay subsoil; high base status, high activity clays	8, 7, 11, 12	Chromosols, Sodosols, Dermosols (DE), Kandosols (KA)
28	Lixisols	Clay subsoil, high base status, low activity clays	8, 7, 11, 12	Chromosols, Sodosols, Dermosols, Kandosols

3. Definition and levels of ESP

In the ASC, the Exchangeable Sodium Percentage (ESP) is defined as

$$\frac{\text{Exchangeable Na.100}}{\text{Effective Cation Exchange Capacity (ECEC)}} \quad (1)$$

In the WRB, ESP is defined as

$$\frac{\text{Exchangeable Na.100}}{\text{Cation Exchange Capacity (CEC at pH 7)}} \quad (2)$$

or $Na + Mg > (Ca+H+Al)$ @ pH 8.2 (3)

The use of ECEC as a denominator is particularly relevant to Sodosols in Victoria where subsoils are neutral or slightly acidic, thereby reducing the relative concentration of sodium. This is because ESP is often calculated with a denominator of the exchangeable bases (i.e. Σ Ca+Mg+K+Na) (e.g. Rengasamy and Churchman 1999). This would be similar with denominators of ECEC or CEC where soils are alkaline, but not where pH is lower owing to higher levels of exchangeable H and Al. The definitions of soil sodicity used in Australia have included ranges of ESP (Northcote and Skene 1972) and the Sodium Adsorption Ratio (e.g. Rengasamy *et al*. 1984). In the ASC sodic soils are defined as ESP $\geq$ 6, with values between 6 and 15 termed 'subnatric', 15-25 'mesonatric' and greater than 25 'hypernatric'. On the other hand, whilst the lower sodicity limit in the WRB scheme is 15 ('natric'), the only subcategory for an ESP qualifier lies in the range of 6-15 ('hyposodic').

4. Role of other factors

The significant criteria used in identifying and diagnosing sodicity for the two classification systems are presented in Table 2. The effects of pH on sodic soil classification have been considered elsewhere (Figure 2, Rengasamy and Olsson (1991) and the values of samples tested at $pH_{1:2.5}$ are likely to be lower than for $pH_{1:5}$ (P Rengasamy pers. comm.).

Table 2. Comparative criteria for Sodosols (ASC) and Solonetz (WRB).

Factor	Sodosol (ASC)	Solonetz (WRB)
Texture	Texture contrast profile. Diagnostic Subsoil Horizon (DSH) has ≥20% clay than the overlying surface soil	n.a.[1]
	n.a.[1]	Natric horizon is loamy sand or heavier or >8% clay content
	n.a.[1]	Less clay in horizon above natric horizon, >1.2 times clay % of material above natric horizon
	n.a.[1]	COLE> 0.04
	n.a.[1]	Clay illuviation
Abrupt texture change	5 cm	7.5 cm
Subplasticity	Not strongly subplastic	n.a.[1]
ESP	≥6	ESP≥15, or Na + Mg> (Ca+H+Al) @ pH8.2
Soil depth	DSH thickness criteria > 0.2 m	Natric horizon thickness criteria
	n.a.[1]	Natric horizon must start within upper 1 m of soil surface
pH	Not strongly acid (pH≥ 5.5)	n.a.[1]
	$pH_{1:5}$	$pH_{1:2.5}$
Structure	n.a.[1]	Structure (i.e. prismatic, columnar)

n.a.[1] not applicable

Results

A comparison of the two classifications and the compatibility between the primary sodic Soil Orders of the ASC (Sodosols) and WRB (Solonetz) was undertaken using four soil profiles (Figure 2) from different regions of Victoria with varying ESP ranges. While the number of soil profiles is limited, they are indicative of varying characteristics and comprise Brown Sodosols [(Nambrok West and Yarram, in south-eastern Victoria and Inverleigh (western Victoria)] as well as a Red Sodosol (Mitiamo, northernVictoria) (Table 3).

Table 3. Comparison of characteristics for the four selected Sodosols (ASC) in Victoria.

Site	$pH_{1:5}$ surface horizon (A1)	$pH_{1:5}$ upper subsoil (B21)	Exch. Bases upper subsoil	ECEC upper subsoil	ESP upper subsoil	ESP lower subsoil	WRB
Nambrok West	5.7	7.3	12.1	12.1	16.5	23.6	Solonetz
Inverleigh	5.8	5.7	16.0	29.0	6.2	22.0	Solonetz
Yarram	5.5	6.3	15.0	29.0	6.2	9.6	Planosol
Mitiamo	5.9	8.1	19.2	n.a.	17.0	32.3	Solonetz

The WRB scheme states that a natric horizon starting within the upper metre of a soil profile defines a Solonetz, but for the ASC the upper subsoil is the diagnostic horizon where the upper subsoil is seen as the major ‘throttle’ on the water and gas movement within the profile. There is no saline Soil Order in the ASC as exists in the WRB (i.e. ‘Solonchak’) and the combination of sodicity and salinity in the ASC and WRB is not prominent in either system. As mentioned earlier, the ESP in the upper and/or lower subsoil is a critical measure in both systems. The Nambrok West profile classification is both a Sodosol and Solonetz due to the high ESP (>15) occurring in the upper and lower subsoil. The soil profile from Inverleigh is also a Sodosol with an ESP between 6 and 15 (identified as Subnatric in the ASC) and also equates to a Solonetz due to greater sodicity (ESP of 22) in the deeper subsoil. The Yarram Sodosol is also classed as a Subnatric Suborder, to a depth of at least one metre and is therefore not a Solontez but a Planosol.

Conclusion

This paper indicates that there is a general alignment between these classifications in terms of a physical concentration of sodium in a soil profile and lighter material overlying a Natric horizon in the WRB scheme as compared with a distinct texture contrast in the ASC. However, significant differences include the definition and measurement of sodicity (i.e. ESP) and its position in the soil profile. More criteria need to be considered for determination of a Solonetz than a Sodosol and this reflects the international aspect of the WRB to accommodate world-wide variability. Accordingly there may be cost considerations in the application of the WRB in particular. However, there are more levels (Order, Suborder, Great Group, Subgroup and Family) in the ASC than the WRB (Order, prefix qualifier and suffix qualifier) allowing greater refinement.

The ASC has undergone progressive refinement since it was introduced in 1996 and the WRB scheme is also being modified. It is considered that ASC data should be extended to a depth of one metre in order to facilitate a direct comparison with WRB and potential extrapolation to the Global Soil Map Initiative. In addition, the colour of Sodosols is a significant characteristic which is not matched to the same degree in the WRB. In this regard, Red Sodosols are a prominent ASC Suborder occurring across the northern riverine plains of Victoria. Although they behave differently to other Sodosols in terms of drainage and waterlogging potential, this soil function information is lost in translation to the Solonetz WRB classification. The addition of a 'Chromic' qualifier to the WRB Solonetz Soil Order to account for the redder subsoil variants would address this issue. Further study is required top establish the relationships between the classifications, for sodium affected soils and extrapolate to other Soil Orders. In terms of sodic texture contrast soils**,** the ASC permits finer categorisation for mapping purposes compared with the WRB. Care is required to facilitate translation between ASC and WRB for publication to an international audience.
It is suggested that a measure of field behaviour reflecting clay dispersion be introduced to both schemes as Electrical Conductivity and other parameters that can exert a strong influence on Exchangeable Na are not taken into account. Options include a test of soil aggregate stability (Emerson 2002) or the measurement of spontaneous and mechanical clay dispersion (Rengasamy 2002).

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