An overview of acid-sodic soils in two regions of New South Wales, Australia

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Abstract

Acid-sodic soils are relatively common throughout eastern New South Wales. Such profiles are thought to be less erodible than the alkaline sodic soils due to the abundance of aluminium and its role in suppressing dispersion. Few studies appear to have been carried out on these soils, although field evidence suggests that they are highly erodible and susceptible to degradation. This paper examines the properties of some acid-sodic soils from two regions of New South Wales - the Northern Rivers region of the far north coast and the Southern Tablelands. The soils examined in the Northern Rivers are generally Grey Kurosols with natric, natric-magnesic or magnesic great groups, and/or sodic subgroups. Soils examined in the Southern Tablelands are generally Yellow Kurosols with natric, natric-magnesic or magnesic great groups or sodic subgroups. Relationships between ESP, dispersion, CEC and aluminium in these profiles were complex and generally no trends were discernible. Exchangeable aluminium and magnesium levels were large. Exchangeable sodium percentage (ESP) was found to be a poor indicator of soil sodicity and dispersive behaviour. Landscape relationships were generally consistent, with most acid-sodic soils occurring in lower slope and depositional positions. The role of parent material (geology), clay mineralogy, landform evolution and climate should be investigated to help further understand the origins and behaviour of these soil types.

Key Words

Sodic, sodicity, Kurosols, natric, acid.

Introduction

Acid-sodic soils are thought to be less erodible than profiles with neutral or alkaline pH due to the abundance of aluminium and its role in resisting dispersion. Few studies appear to have been done on these soils, although field evidence suggests that they are susceptible to degradation and particularly difficult to manage. They are generally found in stable landscapes of the higher rainfall areas (>600 mm per annum). Attempts to quantify or assess the distribution of acid-sodic soils or even sodic soils is somewhat problematic due to the paucity of hard data. Northcote and Skene (1972) assigned approximately 46.7% of New South Wales to sodic soils; 4.2% of these sodic soils were thought to be acidic. As a small step towards redressing this knowledge gap, this paper aims to examine the properties and relative abundance of some acid-sodic soils.

The definition of what constitutes a sodic soil is ambiguous. Sumner (1993) concluded that “no single simple definition is possible”. This problem is further exacerbated when applied to acid-sodic soils. For the purposes of this study acid-sodic soils have been defined as those with an Exchangeable Sodium Percentage (ESP) ≥6% and a pHw <5.5. The problems associated with these limits are briefly discussed below.

Naidu et al. (1995) and Rengasamy and Churchman (1999) provide comprehensive reviews of the problems associated with using ESP for determining sodicity. So and Aylmore (1993) claim that the basis for using ESP>6 as the definition of sodic soil is not well defined and may not always be appropriate, pointing out that no data to date has shown that a threshold value of 6% or 15% for ESP is valid. McKenzie et al. (1993) consider that a critical ESP value should be adjusted according to EC, soil mineralogy and pH. Hulugalle and Finlay (2003) found that the electrochemical stability index (EC(1:5)/exchangeable Na) was a better indicator of dispersion in tilled Vertosols than ESP alone.

Many acid-sodic soils have unusual subsoil chemical features such as large magnesium and large aluminium contents. Although Rengasamy and Churchman (1999) report that there has been considerable debate concerning the influence of magnesium on the behaviour of sodic soils, its effect on enhancing dispersion has been noted (see for example Emerson and Bakker 1973, Emerson and Chi 1977).
Churchman et al. (1993) highlight the influence that soil composition has upon the effect of exchangeable sodium. They make the important point that exchangeable aluminium tends to suppress dispersion but that the influence of soil clay mineralogy on dispersion appears to be less well understood.

In Australia, acid-sodic duplex soils have been classified as Soloths (Stace et al. 1968), Sodic Kurosols and Natric Kurosols (Isbell 1996, 2002). Acid-sodic gradational soils are found across a variety of classes in most systems. These soils cover a range of WRB (FAO 1998) reference groups, including Acrisols, Luvisols, Lixisols, Planosols and Solonetz.

The soil classifications used in the following text are all Australian Soil Classification (ASC) (Isbell 1996, 2002). Acid-sodic soils occur across various orders, great groups and subgroups (Table 1).

Table 1. Acid-sodic soils in the Australian Soil Classification.

<table>
<thead>
<tr>
<th>Order</th>
<th>Great Group</th>
<th>Sub group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kurosols (duplex, upper B horizon pH&lt;5.5)</td>
<td>Natric (ESP ≥6) in upper B horizon</td>
<td>Sodic* (at least the lower part of the B horizon is sodic)</td>
</tr>
<tr>
<td></td>
<td>Magnesic-Natric</td>
<td>Bleached-Sodic*, Mottled-Sodic*</td>
</tr>
<tr>
<td>Hydrosols (prolonged seasonal saturation)</td>
<td>Kurosolic* (upper B horizon pH&lt;5.5)</td>
<td>Sodic* (at least the lower part of the B horizon is sodic)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acidic-Sodic, Ferric-Sodic*, Bleached-Sodic*</td>
</tr>
<tr>
<td>Kandosols (not duplex, massive B horizon)</td>
<td></td>
<td>Acidic-Sodic (upper B horizon pH&lt;5.5 and sodic (ESP ≥6) in at least lower B horizon)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humose-Acidic*, Ferric-Acidic*, Melanic-Acidic*</td>
</tr>
<tr>
<td>Dermosols (not duplex, structural B horizon)</td>
<td></td>
<td>Acidic-Sodic (upper B horizon pH&lt;5.5 and sodic (ESP ≥6) in at least lower B horizon)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humose-Acidic*, Ferric-Acidic*, Melanic-Acidic*</td>
</tr>
<tr>
<td>Vertosols (cracking clay ≥35%, with slickensides)</td>
<td></td>
<td>Episodic-Epiacidic, Episodic-Endoacidic, Epihypersodic-Epiacidic, Epihypersodic-Endoacidic</td>
</tr>
</tbody>
</table>

*Sodic classes are not required when the Great Group is Natric
*both Great group and Subgroup must be met
*subgroup that either by itself or in conjunction with Great Group may fulfill the conditions of an acid-sodic soil
*y Subgroup encompasses both acid-sodic soils and non acid-sodic soils.

The Department of Infrastructure, Planning and Natural Resources (DIPNR) Soil and Land Information System (SALIS) is the repository of soil profile information for NSW. As of July 2004 there are 17 557 profiles with lab data entered into SALIS. Of these 11 665 profiles have been classified in accordance with the Australian Soil Classification.

A total of 1484 soil profiles in SALIS have been classified as Kurosols. This represents 13% of all classified profiles with laboratory results in SALIS. Of these, 215 Kurosols are either Magnesic-Natric or Natric, representing 14% of the total Kurosols. This contrasts with Isbell et al. (1997) who estimated that 41% of the Kurosols are Magnesic-Natric or Natric. This estimate is for all of Australia and not just NSW. It is based on “published data and personal knowledge” (Isbell et al. 1997). The distribution of Kurosols as postulated in Isbell et al. (1997) is described by them as “tentative”.

In SALIS, 26 soil profiles are Magnesic-Natric Kurosols and 189 are Natric Kurosols, representing 2% and 13% of the total Kurosols, respectively. The Natric Great Group is assigned to Kurosols which are sodic in the top 20 cm of the B2 horizon. In some cases, particularly in areas of higher rainfall, the sodicity in the subsoil occurs below the top 20 cm of the B2 horizon. The sodic properties of these soils are classified out at the Subgroup level as Bleached-Sodic Kurosols, Mottled-Sodic Kurosols or Sodic Kurosols. A total of 149 soil profiles, representing 10% of all Kurosols, fall into this grouping.

A total of 364 profiles where classified with some type of sodic/natric Great group or Sub-group, 25% of the total Kurosols. This figure may well be revised upwards upon the completion of the impending SALIS audit. Table 2 summaries the SALIS profiles with laboratory data and one or more acid-sodic layer.
Table 2. SALIS profiles containing one or more layers with acid-sodic soil material

<table>
<thead>
<tr>
<th>Condition</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP &gt;6%</td>
<td>1129</td>
</tr>
<tr>
<td>ESP &gt;15%</td>
<td>590</td>
</tr>
<tr>
<td>ESP &gt;6% and Clay &gt;35%</td>
<td>291</td>
</tr>
<tr>
<td>ESP &gt;15% and Clay &gt;35%</td>
<td>145</td>
</tr>
</tbody>
</table>

Problems associated with sodicity are most notable on heavier soils. There are 291 soil profiles in SALIS with lab data and at least one layer that is a clay (>35% clay particles), strongly acidic (pH<5.5) and sodic (ESP >6). This represents 1.7% of the total number of soil profiles with laboratory data.

Figure 1. Location Map

Case Study 1 - The Northern Rivers region

Location
The Northern Rivers region is located on the far north coast of New South Wales and comprises the catchments of the Tweed, Brunswick and Richmond Rivers (Fig. 1). The climate is subtropical to temperate, with distinct summer maximum rainfall and dry winters. Temperatures are generally mild throughout the year.

Geologically, the Northern Rivers region lies within the Mesozoic Clarence-Moreton Basin (CMB), a structure comprising lithic and quartz sandstones, siltstones, shales and conglomerates. Within New South Wales the CMB is entirely non-marine (Burger 1994). Tertiary volcanics cover much of the CMB and Palaeozoic metasediments outcrop in the eastern parts of the Tweed valley.

Acid-sodic soils
Although widely distributed, sodic soils within the Northern Rivers region are concentrated within the Bungawalbin, a major subcatchment of the Richmond River which occupies an estimated 20% of the total catchment. Mean annual rainfall at the nearby town of Casino is 1107 mm. The geology is dominated by the sandstones, siltstones and shales of the Jurassic Grafton Formation, the youngest of the formations comprising the CMB. These have formed a landscape of rises and low hills encircling a large stagnant alluvial plain/piedmont fan. The soils are generally Grey Kurosols with Natric, Natric-Magnesic or Magnesic great groups, and/or Sodic subgroups.
Figure 2. Relationships between lab results for Northern Rivers region acid-sodic soils. Ex. Al = exchangeable aluminium (me/100g); CEC = cation exchange capacity (me/100g); Al/CEC% = aluminium as a percentage of cation exchange capacity; D% = dispersion percentage; ESP = exchangeable sodium percentage. Sites are indicated in the first row thus: Survey title (W = Woodburn (Morand 2001); L = Lismore-Ballina (Morand 1994); T = Murwillumbah-Tweed Heads (Morand 1996)); site number and layer number.
Other sodic soils examined include a Natric Kurosol occurring on sediments of the Triassic/Jurassic Bundamba Group and a Ferric-Sodic Kandosol occurring on an alluvial plain draining Palaeozoic metasediments, both in the Tweed catchment. A Natric Kurosol has formed on sandstones of the Jurassic Walloon Coal Measures near Nimbin, and a Natric Red Kurosol occurs on the exposed headland at Evans Head. A Natric Kurosol has also formed on quartz sandstone near Lismore. 10 of the profiles examined from the Northern Rivers region are from the Bungawalbin catchment. A summary of the locations and features of the acid-sodic profiles described in this area follows.

W250/3, W35/3, W253/3, W248/4 and L96/2 (see Figure 2) are all located on stagnant alluvial plains or drainage depressions within the Bungawalbin catchment. Sediments are derived predominantly from the Grafton Formation. T31/3 has formed on sediments of Palaeozoic metamorphics in the Tweed catchment. Slopes are <2% and elevation ranges from 2-30m.

W114/3 and W229/4 are located on footslopes derived from the Grafton Formation and occur within the Bungawalbin catchment. Slopes are <2% and elevation is 40-45m. L218/2 occurs on a footslope formed on the Walloon Coal Measures. Slope angle is 12%. There is a large input of rhyolitic material from the upper parts of the landscape.

W227/3 occurs on a lower slope that has formed on the Grafton Formation.

W204/3, W199/3, W208/4, W131/4 and T120/3 occur on crests and upper slopes that have formed on the quartz sandstones of the Bundamba Group. The landscape consists of rises to low hills. Slopes do not exceed 10% at any of the sites. W159/3 and W44/4 occur on crests within rises and low hills of the Grafton Formation. Slopes are <3%. L184/2 occurs on a crest formed on the quartz sandstones of Kangaroo Creek Sandstone.

W99/3 is located on the exposed seaward side of a headland, the underlying geology being the Evans Head Coal Measures.

Landform relationships and features
Within the Northern Rivers region, acid-sodic soils occur on a mix of landforms, but lower slopes/footslopes, stagnant alluvial plains and drainage depressions are the more common. These generally poorly drained environments ensure that sodic subsoils are moist enough to maintain swelling, and they therefore lack the characteristic prismatic/blocky structure generally associated with sodic soils. Overall, the subsoils are sandy clays which have small to large volume expansion and slow permeability. Colours are usually grey with red and orange mottles. Ironstone segregations are often present at the base of the A horizon/s. Melonhole gilgai are a feature of the stagnant alluvial plains. Several tea tree (Melaleuca alternifolia) plantations on these soils have been affected by a puzzling form of tunnel-like erosion, where large holes have formed on level ground.

The acid-sodic soils comprise the poorest and most erodible soils in the region. Once disturbed they are prone to sheet and rill erosion, often possessing a hardset surface of exposed A2 horizon. Large gully systems exist in many drainage lines and depressions.

Geological relationships
Acid-sodic soils in the region are restricted to rocks and sediments of the Clarence-Moreton Basin (CMB) and, to a lesser extent, the Palaeozoic rocks and sediments that form a large part of the eastern Tweed and Brunswick catchments. Of the CMB formations, the Grafton Formation appears to be closely related to sodic soil profiles. This formation also hosts the more saline soils within the region. Soils formed on the Triassic-Jurassic Bundamba Group (sandstones, conglomerates) are also prone to sodicity.

Results
Figure 2 summarises and compares some relevant lab results for the soils investigated in the Northern Rivers region. The data is ranked on the basis of exchangeable sodium percentage (ESP). Dispersion and cation exchange capacity are shown. Dispersion percentage is based on the clay and silt fraction only. Exchangeable aluminium and aluminium as a percentage of cation exchange capacity are shown to give an indication of the possible influence of aluminium in suppressing dispersion.
Nineteen profiles were examined for the Northern Rivers region. The results presented are taken from each profile's diagnostic layer in terms of the Australian Soil Classification (Isbell 2001). pH levels (in water) generally range from 4.5 to 5.8. Clay contents for the Northern Rivers region soils generally range from 35 - 59% (light to medium heavy clays), but two sites, T120/3 and T31/3, have clay contents of 20% and 27% respectively. Dispersion is small to moderate, ESP’s are generally <10, with four being 15 or greater, CEC's range from very small to large, and Al/CEC% is generally very large. Aluminium contents in all these acid soils is large, and certainly the soils with the higher ESPs have relatively lower amounts of Al/CEC% and exchangeable Al. Salt levels in the Northern Rivers region are generally very small (Morand 1994, 1996, 2001), even on the exposed headland site.

Case Study 2 - The Southern Tablelands

Location
The portion of the Southern Tablelands used for this study is the area bounded by the AUSLIG Canberra and Braidwood 1:100 000 map sheets (Fig. 1). The climate is cool and moderately dry (McAlpine and Yapp, 1969). Monthly rainfall is slightly seasonal with warmer months receiving 55 - 65 mm on average, and cooler months 35 - 40 mm (Edwards, 1979). Summer temperatures are generally mild. From April to October frosts are common and of sufficient frequency to limit plant growth.

Geomorphically, the region has a general north-west trend which reflects the strike of the underlying geology. Streams tend to either follow the general north-west trend or cut sharply across it. The region is characterised by a series of mountain and valley systems which follow the general trend.

Geologically, the Southern Tablelands lie within the southern portion of the Lachlan Fold Belt. Ordovician rocks are the oldest and most extensive. They are usually sharply dipping and tightly folded metasediments. Silurian volcanics comprising a range of tuffaceous and rhyolitic materials and granitic intrusions are also common. Fluvial sands and gravels of the ancient Shoalhaven River system occur extensively in the Braidwood Area. They have given rise to extensive areas of sodic soils.

Acid-sodic soils
Sodic soils within the Southern Tablelands are concentrated within the valley systems. The acid-sodic soils generally occupy relict landscapes and footslopes. They tend to be in slightly more elevated positions than the adjacent non-acidic sodic soils. Slopes at most of the sites are much gentler than for the surrounding terrain. A summary of the locations and features of the acid-sodic profiles described in this are follows.

B82/3 (see Figure 3) is located on a very gently sloping site (2% slope). This is set amongst much steeper terrain with slopes up to 20%. The surrounding countryside of undulating to rolling quartzite and arenite low hills and rises has local relief of 10 to 60 m between 650 and 770 m elevation. Soil materials in this area were found to be inherently acid (Jenkins, 1996).

B170/3 and B170/4 occur on rolling low tuffaceous hills. They are located on very gently sloping sites (12% slope) set amongst much steeper terrain. The surrounding countryside consists of slopes between 20 to 32% and local relief of 20 to 50 m. The elevation range is between 590 and 650 m ASL. This is a lower elevation range than for the other Southern Tablelands sites.

C476/3 is found on a gentle slope (8%) set amongst steep to rolling hills on rhyolite. The hillslopes are generally long (>200 m) and steep 20-40%. Local relief is between 100 and 250 m and the elevation range is 700 to 920 m. A very large potential Al toxicity was recorded for the topsoils at the C476 site (Jenkins, 2000).

C470/3 is found on a slope of 27% which is typical of the surrounding countryside. It is the steepest recorded acid-sodic site in this study. The site is set amongst rolling to rugged steep hills and mountains on metasediments. Local relief is up to 300 m between 750 and 1350 m elevation. The surrounding hillslopes are typically cobbled strewn with occasional scree slopes. Very large Al toxicity was found in the topsoils at this site (Jenkins, 2000).
Figure 3. Relationships between lab results for the Southern Tablelands acid-sodic soils. Ex. Al = exchangeable aluminium (me/100g); CEC = cation exchange capacity (me/100g); Al/CEC% = aluminium as a percentage of cation exchange capacity; D% = dispersion percentage; ESP = exchangeable sodium percentage. Sites are indicated in the first row thus: Survey title (C = Canberra (Jenkins 2000); B = Braidwood a (Jenkins 1996)); site number and layer number.

C136/3 occurs in a upper slope position on a slope of <10%. Slope gradients for much of the surrounding rolling to steep hills and low hills on metasediments are 10-30%. The hill slopes are mostly cobble strewn. The local relief is up to 200 m between 600 and 1000 m elevation. C136/3 is magnesic (Jenkins, 2000).

C318/3 and C318/5 occur on a waning lower slope (7% slope) fan derived from colluvial parent material. The general area has local relief up to 30m between 580 and 670m elevation. Slopes tend to be moderately inclined < 20%. C318/5 was highly saline and both C318/3 & C318/5 are magnesic (Jenkins, 2000).

Landform relationships and features

Within the Southern Tablelands study area, acid-sodic soils occur on a mix of landforms, but lower slopes/footslopes, relict alluvial deposits are the most common. Typically the acid-sodic soils were found on the gentler sloping areas within steeper landscapes. They often occurred on relict land surfaces.

All of the Southern Tablelands acid-sodic soils occur in slightly higher rainfall areas and slightly more elevated terrain than for the bulk of the sodic soils that characterise the Braidwood and Canberra map sheets (Jenkins, 1996).

Site drainage at all the described Southern Tablelands sites is imperfect to poor. Subsoil colours are yellow to brown with various degrees of mottling. This is indicative of seasonal waterlogging which is typical of the Southern Tablelands acid-sodic soils.
The acid-sodic soils comprise some of the poorest and most erodible soils in the Southern Tablelands. They are prone to sheet and rill erosion, often possessing a hardset surface of exposed A2 horizon.

**Geological relationships**
Acid-sodic soils in the Southern Tablelands occur on Ordovician metasediments, Silurian volcanics and Tertiary sediments. Lithologies include siltstones, quartzites, rhyolites, tuffs and alluvium.

**Results**
Fig. 3 summarises and compares some relevant lab results for the soils investigated in the Southern Tablelands. Six profiles were examined for the Southern Tablelands. The results presented are taken from each profile’s diagnostic layer/s in terms of the Australian Soil Classification (Isbell 2001). pH levels (in water) generally range from 4.0 to 5.0. Clay contents vary greatly for the Southern Tablelands ranging from 17 to 55%. Dispersion is highly variable, ESP’s are small (<12), CECs are generally very small and, Al/CEC% is generally very large. Aluminium trends are similar to those of the Northern Rivers region soils. Some of the Southern Tablelands profiles contained salt at depth (Jenkins 1996, 2000).

**Discussion**

1. **Laboratory data**
In contrast to the acid-sodic soils of the Northern Rivers region the soils of the Southern Tablelands have the characteristic prismatic/blocky structure generally associated with sodic soils and exhibit little or no swelling. C318/3 had the greatest volume expansions of any of the Southern Tablelands samples at 20% (Jenkins 1996, 2000).

Figs 2 and 3 illustrate a complex picture and show that the relationship between sodicity, as determined by ESP, and dispersion is not clear cut. Several features are worth noting:

i. For the same value of ESP, dispersion percentages are variable. Also, there is no trend suggesting that larger ESP’s have greater dispersion - the sample with the largest ESP value does not have the largest dispersion percentage.

ii. Where Al/CEC% is small (W159/3, W99/3, W229/4, C318/5, C318/3, C476/3) ESP varies from the smallest value (6) to the largest value (31). Dispersion for these samples would be expected to be relatively large (as it is in W159/3) but it too is variable.

iii. Examining general trends, the relationship between Al/CEC% with ESP appears to have some consistency for the Northern Rivers region, the smaller ESPs occurring in those samples with the greater Al/CEC%. The relationship between Al/CEC% and dispersion percentage is variable.

iv. CEC’s do not appear to have any consistent relationship with either ESP or dispersion percentage. The wide range of values may reflect differences in clay mineral suite.

Data shown in Figs 2 and 3 strongly suggests that in the Northern Rivers and Southern Tablelands factors other than sodicity and dispersion are responsible for the origin and behaviour of the region’s acid-sodic soils. There are no obvious trends in the data presented and the use of ESP as a diagnostic criteria for sodicity seems to be inadequate. Other results not presented in Figs 2 and 3 are salinity and magnesium levels. Salt levels are generally very small, while exchangeable magnesium is consistently large (Morand 1994, 1996, 2001). Thus dispersion would not seem to be reduced by large salt contents, whereas the role of magnesium may be more significant than sodium.

2. **Sodicity in the Northern Rivers Region and Southern Tablelands**
Charman (1970) attributes sodicity in Northern Rivers region to the continual leaching effect of rainfall charged with salt. He concludes that the near coastal location and poor subsoil permeability facilitate cyclic salt accession. Isbell et al. (1983) dispute this process, and the small EC values of the profiles examined seem to support them. They cite references that claim there is enough sodium in parent rocks to provide suitable sources for salt and sodium. Chartres (1993) adds a third possible source of sodium - groundwater. Mineralogy of the parent rock and groundwater are possibly the important contributors to sodicity in the Northern Rivers region. This is evidenced by the close relationships between certain geological formations (and probably to specific lithologies within these formations) mentioned above.

Wells and O’Brien (1994), for instance, reported a high proportion of plagioclase in the shales of the...
Walloon Coal Measures. Similar data for other formations within the Clarence-Moreton Basin are not known to be available. Groundwater may be an important issue in the Bungawalbin catchment. McGrath and Boyd (1998) found strong palynological evidence of estuarine conditions (including high soluble sodium) in the lower Bungawalbin alluvial plain. During the Holocene the overall trend was towards increasingly drier conditions (McGrath and Boyd 1998). Thus, conditions would appear to favour the accumulation and concentration of sodium during the Holocene, at least within the alluvial plain.

Much of the laboratory data seemingly contradicts field observations, where the field evidence suggests large dispersion. The soils examined in the Bungawalbin have small to moderate dispersion but exhibit features typical of largely dispersive soils, in particular large gullies. Such erosive features may occur as a result of a combination of factors working in concert. Soils with moderate dispersion due to large sodium and/or magnesium contents being buffered by large aluminium, are still very prone to erosion during the intense summer rainfalls that occur on the north coast of New South Wales. Gully erosion is rare on the non-sodic soils in similar environments.

The Southern Tablelands lacks the intense summer rainfall of the Northern Rivers region yet the highly erodible nature of the acid-sodic soils is once again borne out by field observation. B82/3, C318/3, C318/5 all had very small dispersion percentages yet field observations suggested that they were highly erodible soils (Jenkins 1996, 2000).

Thus, there may be a threshold value where dispersion in the field is controlled by the amount and intensity of rainfall, sodium, magnesium and aluminium contents and salinity. Texture may also play a role, as most of the sodic subsoils are sandy clays which are susceptible to mechanical breakdown; presumably as the clays disperse sand grains are removed. Many soils with small dispersion exhibit worminess on exposed faces where flows of sand-laden dispersed material have dried.

3. Relative abundance of acid-sodic soils
At over 17 000 profiles with laboratory data, SALIS has an impressive number of samples from which to draw information. The soil data is clearly skewed towards particular areas of interest with some portions of the state still poorly represented in the database. Much of the coast, central tablelands, and selected portions of the western slopes (Wagga Wagga and Forbes areas) and Liverpool Plains have good coverage. Areas such as most of the Riverina, the far west of the state and the Southern Highlands have a paucity of profiles in SALIS. Therefore, the abundance figures for acid-sodic soils cannot be assigned as a figure which represents a percentage of the land area of NSW. The figures do, however, give some indication of the relative abundance of these soils within profiles examined across the state. A total of 6.4% of the soil profiles with laboratory data were found to have at least one acid-sodic layer.

Conclusions
Rengasamy and Olsson (1991) state that detailed studies of acid-sodic soils are needed to examine the mechanisms controlling their dispersive behaviour. Thus far it appears that little has been done. The acid-sodic soils examined in this paper confirm that there is much scope for further study. Likewise, the applicability of ESP as a measure of sodicity is confirmed as being of dubious value. Our understanding of these soils will be enhanced by several means. The influence of magnesium needs to be investigated. Aluminium, exchangeable sodium and salinity relationships need to be explored and replacements sought for ESP. Landscape evolution studies, mineralogical analyses of parent material and soil, and climate relationships will help us to understand the sources of sodicity and its potential impacts, particularly in acid environments. At 6.4% of the total number of soil profiles within SALIS, acid-sodic soils are clearly a significant component of the soils of NSW and deserve closer scrutiny.
References


