The World Reference Base for Soils (WRB) and Soil Taxonomy: an initial appraisal of their application to the soils of the Northern Rivers of New South Wales

David T. Morand[A, B]

[A]School of Environmental Science and Management, Southern Cross University, PO Box 157, Lismore, 2480, NSW, Australia.
[B]Department of Environment, Climate Change and Water, PO Box 856, Alstonville, 2477, NSW,
Email David.Morand@environment.nsw.gov.au

Abstract
Few, if any, soil surveys in New South Wales have utilised international soil classifications. Extensive morphological and laboratory data collected during soil survey in the region provided a strong basis for correlation with the World Reference Base for Soil Resources (WRB) and Soil Taxonomy. Of the 32 reference soil groups composing the WRB, 19 were found to exist locally; 9 of the 12 Soil Taxonomy orders were present. Several correlation problems were apparent, most of which are common to both international schemes. Fundamental reliance on laboratory data is probably the most outstanding limitation. Soils with strong texture-contrast are not adequately differentiated to suit Australian conditions. Of the two international schemes, the WRB seems to have more appropriate classes and was consequently the easier to apply locally, although it is evident that more Australian input is necessary in order to make this a truly international soil classification/correlation scheme.

Key Words
Soil classification, soil correlation, soil survey, Australian soil classification.

Introduction
There are two soil classification schemes that are generally regarded as having worldwide application - the World Reference Base (WRB) (IUSS Working Group WRB 2006) and the USDA Soil Taxonomy (Soil Survey Staff 1999). Neither has been popular in Australia, although some state authorities have identified major soils in soil survey reports in terms of the USDA Soil Taxonomy (Isbell 1992). The lack of interest in international classification schemes is not surprising given this continent's unique landscape and soil evolution and its marked difference to Northern Hemisphere conditions. However, consideration of international systems is becoming increasingly important for communication of soil studies and knowledge. This situation was highlighted recently when the Australian soil science community received criticism for its lack of contribution to the development of the World Reference Base (Gray 2003) despite warnings of the hazards of ignoring international soil classifications (Isbell 1992, McKenzie 2003).

As a small step towards stimulating interest in utilising international soil classification schemes, soil data collected during soil surveys within the Northern Rivers of New South Wales has been utilised to correlate the Australian Soil Classification (ASC, Isbell 2002) with the WRB and Soil Taxonomy. Emphasis has been given to the WRB in this exercise because it was devised for correlation with national classifications. The application of the schemes has been considered from a broad-scale mapping context.

Many of the dilemmas associated with applying the WRB and Soil Taxonomy to Australian conditions are discussed in Isbell (2002) and Isbell, McDonald and Ashton (1997). The soils of the Northern Rivers are no exception.

The Northern Rivers - a brief overview
Location
The Northern Rivers are located on the far north coast of New South Wales, Australia (Figure 1).

Climate
The climate is subtropical to temperate, with distinct summer maximum rainfall and dry winters. Temperatures are generally mild throughout the year.
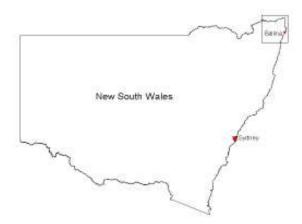
Figure 1. Location of the Northern Rivers of New South Wales.

Geology
The Northern Rivers lie within the Mesozoic Clarence-Moreton Basin (CMB), a structure comprising lithic and quartz sandstones, siltstones, shales and conglomerates. Draping much of the Northern Rivers section of the basin are Tertiary volcanics that have originated from the Tweed Shield Volcano, centred in the Tweed Valley, and the Focal Peak Volcano, located in southeast Queensland. The lavas are dominated by basalt with lesser amounts of acid volcanics. Large areas of Quaternary alluvium occur throughout the region and extensive Quaternary sand bodies flank the coast. Palaeozoic metasediments form much of the landscape of the eastern part of the catchment.

Soils
Brown, Yellow, Red and Grey Kurosols generally form on the sedimentary rocks of the CMB and the metasediments. Red Ferrosols and Brown Dermosols are found on the basaltic hills, while Vertosols occur on basaltic footslopes and drainage depressions. Soils formed on alluvium are variable, but Vertosols are dominant where basalt is the major source of sediment. Otherwise Grey Kurosols, Dermosols, Kandosols, Vertosols and Hydrosols occur in varying combinations. Podosols have formed on the coastal sand bodies, interspersed with Organosols. Sulfidic or Sulfuric Hydrosols generally occupy estuarine areas.

Soil Landscape Mapping
Soil landscape mapping undertaken by the Department of Environment, Climate Change and Water (DECCW) and its predecessor organisations has provided the basis for this study. Three relevant soil landscape maps and reports exist: Lismore-Ballina, Murwillumbah-Tweed Heads and Woodburn (Morand 1994, 1996, 2001). A fourth, Western Richmond, is underway. The scale of mapping is 1:100 000 and data collected includes detailed soil profile descriptions and comprehensive laboratory analyses. All the ASCs were correlated as closely as possible with the WRB and Soil Taxonomy. Although soils were classified to qualifier level (WRB) and to subgroup level (Soil Taxonomy), only the primary reference groups or orders have been reported in this paper due mainly to space limitations.

Results and Discussion
Table 1 shows the equivalent WRB and Soil Taxonomy classes found in this study based on 141 profile descriptions with complete lab data. 19 of the 32 WRB reference groups and 9 of the 12 Soil Taxonomy orders were found to be present within the Northern Rivers.

General Comments
The outstanding difference between the international schemes and the ASC is the very high level of dependence on lab data in the former.

Assuming the resources are available, the lab tests required for WRB and Soil Taxonomy should not pose a problem in themselves, but in the Northern Rivers (and Australia in general) these resources, including pedologists, are minimal. In deriving many WRB and Soil Taxonomy classes using the available data many presumptions are required.

Table 1. Australian Soil Classification and international equivalents as applied to soils of the Northern Rivers, NSW. Figure in brackets is the number of profiles classified (total classified is 141).

ASC	WRB	Soil Taxonomy
Dermosols(15)	Luvisols(4), Acrisols(3), Phaeozems(3), Cambisols(2), Lixisols(2), Chernozems(1)	Mollisols(6), Ultisols(4), Inceptisols(3), Alfisols(1)
Ferrosols(8)	Nitisols(5), Acrisols(2), Lixisols(1)	Oxisols(4), Ultisols(3), Alfisols(1)
Hydrosols(24)	Gleysols(10), Fluvisols(6), Planosols(2), Histosols(1),Phaeozems(1), Acrisols(1), Luvisols(1),Lixisols(1), Solonchaks(1)	Inceptisols(8), Alfisols(8), Mollisols(3), Entisols(3), Histosols(1), Vertisols(1)
Kandosols(11)	Acrisols(4), Lixisols(2), Gleysols(1), Cambisols(1), Phaeozems(1), Luvisols(1), Planosols(1)	Alfisols(6), Mollisols(3), Ultisols(2)
Kurosols(44)	Acrisols(25), Lixisols(6), Planosols(6), Luvisols(4), Solonetz(2), Regosols(1)	Alfisols(23), Ultisols(21)
Organosols(1)	Histosols(1)	Histosols(1)
Podosols(17)	Arenosols(11), Podzols(6)	Inceptisols(11), Spodosols(4), Entisols(1), Mollisols(1)
Rudosols(1)	Regosols(1)	Entisols(1)
Sodosols(2)	Solonetz(2)	Alfisols(2)
Tenosols(10)	Regosols(4), Lixisols(3), Arenosols(2)	Inceptisols(4), Entisols(4), Mollisols(2)
Vertosols(7)	Vertisols(7)	Vertisols(7)
Anthroposols(1)	Technosols(1)	

Those classes based predominantly on morphology were the simplest to correlate. Thus Vertosols (ASC) were relatively easy to correlate with Vertisols (WRB and Soil Taxonomy). Podosols generally fitted into Podzols (WRB) and Spodosols (Soil Taxonomy), in spite of some diagnostic tests being required for the international schemes. Where diagnostic horizons occurred below 2m, as is common with many of the Podosols in the Northern Rivers, they were easily classified as Arenosols (WRB) and Inceptisols (Soil Taxonomy). In comparison, six WRB reference groups were found to be equivalent to Kurosols (ASC) - Acrisols, Lixisols, Planosols, Luvisols, Solonetz and a Regosol. The Planosols and Solonetz can generally be distinguished by morphology, but the remainder are soils with argic horizons that are discriminated by lab data alone, making them difficult to identify in the field. Within the Northern Rivers there were no apparent morphologic or geomorphic features that assisted in identifying these particular soils. However, the reference soil group most commonly equated with the strongly acidic (pH$_w$<5) Kurosols is the low base status Acrisols (Table 1), confirming that field pH can assist in determining a field classification.

Texture differentiation, though accommodated in the international schemes, is not treated with the same degree of importance as in Australia. Hubble *et al.* (1983) noted the widespread occurrence of texture-contrast soils, often with sodic subsoils, as being a feature unique to this country. This is reflected in the ASC orders specifically defined by abrupt textural changes, notably the Kurosols, Chromosols and Sodosols. Within the international schemes, soils containing an argic (WRB) or argillic (Soil Taxonomy) horizon with an abrupt textural change, the nearest equivalent to the *clear or abrupt textural B horizon* (ASC) occur in several ASC orders. The ASC and the international schemes have differing criteria for (i) clay content increases, (ii) minimum clay contents in the argic/argillic horizon and (iii) sharpness of horizon boundary changes. More substantial clay increases over sharper boundaries (Isbell 2002, McDonald and Isbell 2009) are required for ASC texture-contrast soils. Use of WRB and Soil Taxonomy tends to group such soils with others that, by Australian standards, lack strong texture-contrast.

One aspect of both the WRB and Soil Taxonomy that facilitated easier classification is the use of depth intervals for diagnostic horizons rather than using specific designated horizons. The high level of importance given to the identification of the B horizon in the ASC can be a problem if that horizon cannot be identified, such as in many Podosols (or if it is misidentified by the soil surveyor).

Both international schemes have classes for disturbed soils, albeit at different hierarchical levels. The WRB has the Anthrosol and the Technosol reference groups, Soil Taxonomy has relevant subgroups. Technosols generally equate with the Anthroposols (soils resulting from human activities) of the ASC. Anthrosols and the Soil Taxonomy subgroups generally apply to agricultural soils that have been modified over centuries - neither correlated with the Anthroposols.

Conclusions

Despite some problems, the WRB can and should be used for soil correlation in the sub-tropical and temperate areas of northern New South Wales. Indeed Powell (2008) recommends using the WRB whenever possible. Although dependence on laboratory data is a problem, there is no reason why soils can't be correlated using confidence levels as is done in the ASC (WRB does recognise the use of an initial field classification, roughly equivalent to ASC confidence levels 2 or 3). The Australian soil science community needs to contribute more local perspective to the WRB. For example, the addition of a qualifier, or even a new reference group, that takes into account soil texture changes with sharp or abrupt boundaries ("duplexic"?) may be appropriate for Australian conditions.

On the other hand, Soil Taxonomy seems to have limited value due to its greater reliance on laboratory data. Murphy and Murphy (2000) briefly review Soil Taxonomy, providing some good reasons as to why it has limited applicability to Australia.

The use of the WRB as a complement to the ASC will only strengthen Australia's capacity for unambiguous communication with the world soil community. Furthermore, the nature of the WRB, its reference groups and their derivations and the analyses required, enable soils to be considered from a viewpoint other than that provided by the ASC - this can only enhance our quest for the understanding of soil formation, soil behaviour, and soil and landscape relationships.

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