A COMPARISON OF BASALTIC SOILS AND ASSOCIATED VEGETATION PATTERNS IN CONTRASTING CLIMATIC ENVIRONMENTS.

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INTRODUCTION

Soils formed on Tertiary basalt within the wet sub-tropical far north coast of New South Wales contrast markedly with those forming on similar aged basalts on the Monaro tableland. This paper discusses the reasons for these differences.

1. THE FAR NORTH COAST, NSW

Overview

For the soils (classified as Red Ferrosols (Krasnozems)) formed on the far north coast of NSW, vegetation-soil relationships are not strong. Subtropical rainforest, now extensively cleared, was widespread over areas such as the Alstonville plateau in the Richmond River catchment and the Cudgen plateau in the Tweed River catchment. Although almost too numerous to list, the rainforest trees included *Heritiera trifoliolata* (white booyong), *Ficus watkinsiana* (strangling fig) and *Toona ciliata* (red cedar). Present-day vegetation is generally dominated by volunteer pasture species, mainly *Pennisetum clandestinum* (kikuyu) and *Paspalum dilatatum* (paspalum). Remnants of the original vegetation exist in a few small reserves but a major impediment to rainforest re-establishment is competition from the prolific exotic *Cinnamomum camphora* (camphor laurel).

The rainforests give way to eucalypt forests where Palaeozoic metamorphic rocks or Mesozoic sedimentary rocks outcrop—the soils (generally Kurosols) being shallower, stonier and generally less structured than those on basalt.

Areas of basalt in the western parts of the region experience lower rainfall regimes and the soils are generally shallower and less weathered, being Brown/Black Dermosols (Chocolate Soils, Prairie Soils). Vegetation in these drier parts is dominated by eucalypt forests. Pockets of subtropical rainforest occur on localised areas of deep red soils (Ferrosols) which appear to be forming on iron-rich tuffaceous material.

Geology and landforms

Soils have formed on Tertiary (Eocene/Oligocene) basalts—the Lismore Basalts—that are part of the Lamington Volcanics. These basalts originated as lava flows emanating from the Tweed Shield Volcano, the prominent Mount Warning now plugging the central vent. The formation of the volcano has been attributed to 'hotspot' activity as the Australian continent drifted north. Other ancient shield volcanoes, such as the Warrumbungles and the Nandewar Ranges, are believed to be related to the same 'hotspot' (Johnson 1989). Basaltic flows are extensive and cover an area of 2,500 km^2, centred around Mount Warning. Olivine is common (McElroy 1962). Narrow bands of tuff occur throughout the basalts. Flow thickness is in the order of 200-500m (McElroy 1962).

Within the far north coast of New South Wales Ferrosols (Krasnozems) are commonly associated with undulating to rolling rises and low hills but are by no means restricted to these landforms. Mass movement, usually shallow slumps, is a relatively common feature throughout the landscape. Benching is often evident in the steeper rolling country.

Soils

Soils are highly weathered and are generally *Acidic, Dystrophic Red Ferrosols* (Krasnozems). Kaolin is the dominant clay mineral along with variable amounts of hematite, goethite and gibbsite (Norrish & Pickering 1983). Exceptional structure is the defining characteristic of these soils. Other distinctive features are:

- depth (generally > 150 cm);
- very well drained;
- red colours;
- strong acidity;

- strong aggregation of peds and almost total lack of any dispersion in the topsoil (Tables 1 and 2).
- very high phosphorus sorption;
- high exchangeable aluminium in subsoils and possible toxicity problems;
- low Cation Exchange Capacity (CEC) in subsoils (see Tables 1 & 2).

Table 1: Soil profile with lab results – *Alstonville Plateau, Richmond Catchment.*

Acidic, Dystrophic Red Ferrosol
Alstonville Plateau,
Richmond Catchment,
Far North Coast, NSW

Topsoil (0-20 cm)

pH($CaCl_2$): 4.1.
Organic Matter: 6.56%.
PSA Clay (mechanical): 22%.
Cation Exchange Capacity: 12.6 cmol/kg.
Exchangeable Aluminium: 1.8 cmol/kg.
Phosphorus Sorption: 819 ppm.

Subsoil (20-100+ cm)

pH($CaCl_2$): 4.0.
Organic Matter: 2.26-0.97% with depth.
PSA Clay (mechanical): 0%. *
PSA Clay (dispersion): 80%. *
Dispersion %: 0.
Cation Exchange Capacity (CEC): 12.2-17.1 cmol/kg with depth.
Exchangeable Aluminium: 8.3 cmol/kg.
Phosphorus Sorption: 819-814 ppm.

Table 2: Soil profile with lab results - *Tweed Catchment*

Acidic, Dystrophic Red Ferrosol
Tweed Catchment,
Far North Coast, NSW

Topsoil (0-10 cm)

pH($CaCl_2$): 5.2.
Organic Matter: 8.9%.
PSA Clay (mechanical): 34%.
Cation Exchange Capacity: 13.9 cmol/kg.
Exchangeable Aluminium: 0.3 cmol/kg.
Phosphorus Sorption: 841 ppm.

Subsoil (10–3,000+ cm)

pH($CaCl_2$) 5.7-3.8 with depth.
Organic Matter: 1.5-0.51% with depth.
PSA Clay (mechanical): 0%. *
PSA Clay (dispersion): 50-70%. *
Dispersion %: 0-3.
Cation Exchange Capacity: 9.4-20.9 cmol/kg with depth.
Exchangeable Aluminium: 14.6 cmol/kg.
Phosphorus Sorption: 841-870 ppm.

* Note: PSA Clay (mechanical)/(dispersion) figures are correct. Subsoils are very Fe- and Al-rich making them very non-dispersive (mechanical test) unless treated with a dispersing agent (dispersion test).

Climate

The far north coast of New South Wales has a warm temperate climate with a pronounced summer and autumn wet season and drier winters and springs. The region is also one of the wettest areas in the State, with some of the most erosive rainfall in New South Wales. Rainfall data (derived from Bureau of Meteorology website—BOM) for the Alstonville area is summarised below (Figure 1).

Average annual rainfall for the far northeastern corner of the State ranges from 1550-1800 mm/year, declining to 1200-1420 mm/year in the drier western parts. Temperatures are mild and generally not a limitation to plant growth.

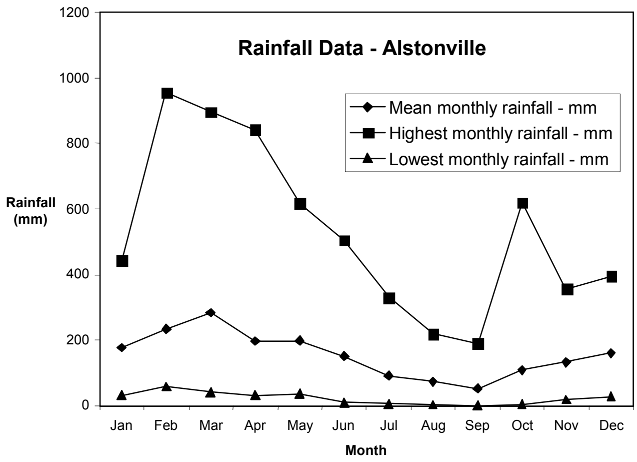

Figure 1: Rainfall data for Alstonville, NSW. Source: Bureau of Meteorology (BOM).

2. THE MONARO BASALTS, NSW

Overview

Soils formed on the basalts of the Monaro Volcanic Province on the Monaro Tableland are generally classified as Brown Dermosols and have traditionally been referred to as Chocolate Soils.

The relationship between the Chocolate Soils and vegetation is strong. The dense, poorly aerated subsoils are not favourable to most alpine and sub-alpine native tree and shrub species. Tussock grasses dominate and include *Poa* spp. (snow grass) *Stipa* spp. (spear grasses), *Themeda triandra* (kangaroo grass), *Bothroichloa macra* (red grass) and *Danthonia* spp. (wallaby grass). Grazing pressures tend to determine the relative distribution of these grasses. Themeda prefers lesser grazed sites and may have once dominated the Monaro basalt. *Poa* spp including *Poa sieberiana* (snow grass), *Poa labillardierii* (river tussock) and *Poa caespitosa* (tussocky poa) are now dominant over most of the Monaro. *Poa labillardierii* dominates wet sites and on drier sites *Poa sieberiana* tends to be co-dominant with *Danthonia* spp. or *Stipa* spp. *Bothroichloa macra* tends to favour sites which are recovering from over-grazing (R. Rewinkle pers. comm.).

Geology and landforms

Soils have formed on Tertiary (Eocene/Oligocene) basalts derived from a multi-fissured lava field (Pratt *et al.* 1993). Roach *et al.* (1994) referred to the region as the Monaro Volcanic Province and estimates it covers some 4,200 km^2. The basalt extends for over 100 km from near Adaminaby to Cooma and is over 40 km wide (Branagan & Packham 2000). From a core through the lava pile Brown *et al*. (1992) inferred *'a basalt thickness of up to 400 m'*. Olivine phenocrysts and ashes are common (Tulau 1994) as are interbedded Tertiary sediments, hyaloclastites and thick weathering profiles which are often bauxitic (Roach *et al.* 1994).

The Monaro is predominantly a gently undulating plain with areas of undulating rises and minor low hills. More than 65 volcanic plugs are found within the plain, most of these stand as high points within the landscape (Roach *et al.* 1994). Numerous small deflation basins have formed lakes within the plain. The largest and deepest of these only dry out during periods of prolonged dryness. Most of the Monaro lakes have aeolian shadows spreading from their eastern shores (Pillans 1987). In contrast to the North Coast basalt landscapes mass movement is a relatively uncommon feature.

Soils

Soils are generally *Basic, Eutrophic, Brown Dermosols* (Chocolate Soils). Montmorillonite is the dominant clay mineral (Costin 1954). The cation exchange is dominated by basic cations particularly calcium and magnesium. Clay contents are high and soils are well structured. Surface soils can be self mulching. Other distinctive features are:

- depth generally < 75 cm, but may be > 150 cm on lower slopes.
- brown colours;
- slight acidity decreasing down the profile
- strong aggregation of peds.
- phosphorus sorption is only moderate to high, tend to be potassium deficient (see Table 3).

The Monaro laboratory results did not include PSA Clay (dispersion). The disparity between field textures and PSA Clay (mechanical), see Table 4, suggest that PSA Clay (mechanical) does not give accurate clay content measurements for these soils.

Climate

The climate of the Monaro Tablelands of New South Wales ranges from a cool to warm semi-arid to a cool to warm sub-humid climate. The Snowy Mountains to the west and the Coastal Range to the east result in elevated levels of rainfall on the crests and rain shadow in the Cooma Region. This rain shadow extends in a SSW direction encompassing much of the lava field. Rainfall in the rain shadow areas tends to *'occur as heavy short duration events'* (Tulau 1994). Rainfall data (BOM) for the Monaro area is summarised below and in Figure 2.

Average annual rainfall over the Monaro Volcanic Province ranges from 450-1150 mm. The lowest rainfall is to the east of Cooma, the southern-most range of the Bredbo–Cooma rain shadow. The highest recorded average annual rainfall of 1115 mm occurs near Brown Mountain (Bureau of Meterology site 70237 – Nimmitabel (Cottesloe)) which is a basaltic outlier of the Monaro Volcanic Province. Rainfall is typically between 500–700 mm for most of the Monaro Volcanic Province.

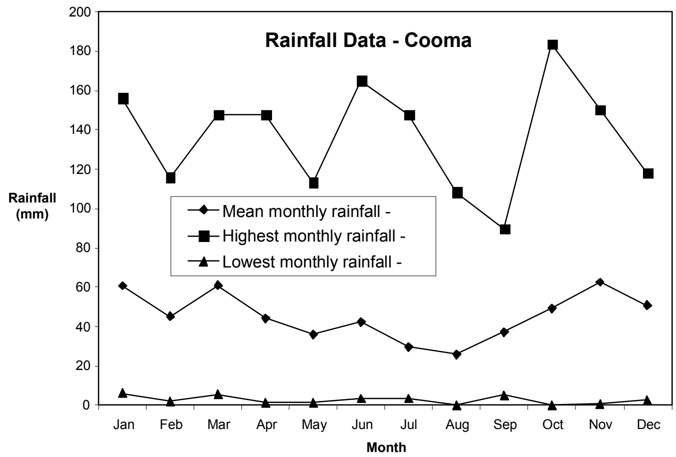

Figure 2: Rainfall data for Cooma, NSW. Source: Bureau of Meteorology (BOM)

When soil moisture for plant growth is adequate temperatures, particularly the occurrence of frost, preclude plant growth. Foley (1945) found a yearly average of 72.4 heavy frosts (screen temperatures below 0^0C) for Bombala.

Table 4: Difference between estimated clay contents from field textures and PSA Clay (mechanical) for the soil profile described in Table 3.

Soil Layer	Field Texture (est clay %)	PSA Clay (mechanical)
Fig 1 Topsoil	clay loam (30-35)	21
Fig 1 Subsoil	sandy clay (35-40)	29

Table 3: Soil Profile from Monaro Basalts with Lab Results.

Basic, Eutrophic, Brown Dermosol
MonaroTablelands
Southern Highlands, NSW

Topsoil (0-15cm)

pH($CaCl_2$): 6.4.
Organic Matter: 1.63%.
PSA Clay (mechanical): 21%.
Dispersion: 7%.
Cation Exchange Capacity: 27.1cmol/kg.
Phosphorus Sorption: 593ppm.
Volume Expansion: 36%

Subsoil (18-57cm)

pH($CaCl_2$): 5.0
Organic Matter: 0.77%
PSA Clay (mechanical): 29%.
Dispersion %: 12.
Cation Exchange Capacity (CEC): 33.5 cmol/kg
Phosphorus Sorption: 680 ppm.
Volume Expansion: 29%

DISCUSSION

A number of factors in combination have resulted in the treeless nature of the Monaro Volcanic Province. These include: low precipitation; severe frost; low plant available water; poorly aerated subsoils; and severe wind chill. In comparison, the forest communities growing in most soils on the far North Coast exist due to high rainfall. The high rainfall and differences in parent material account for differences in soil types and specific vegetation communities. Unlike the Monaro Volcanic Province, there are virtually no naturally treeless areas on the far North Coast.

A shearing effect on the root zone of tree species has often been cited as a probable cause for the treeless nature of the Monaro Volcanic Province. However, Tulau (1994) claimed that there *'is no merit in the widespread belief that shrink-swell properties of these soils is involved'*. The volume expansion values (29% & 36%) shown in Table 4 support Tulau's assertion. These values are low in comparison to other treeless grasslands where shrink-swell properties are a major factor. *Stipa aristiglumis* (plains grass) grassland is a feature of the Liverpool Plains in North Western NSW. Banks (1995, 1998, 2001) typically found volume expansion values for the Liverpool Plains in excess of 50%. Soil depth must also be taken into account when determining the effect of shrink swell properties on species composition. In the Liverpool Plains example Banks was often unable to determine the depth of soil materials other than that they were in excess of 300 cm deep. The large volume of expansive material allows for large fluctuations in the ground surface and large amounts of shear force to be exerted on plant roots. On the Monaro the reverse is true as soil depths are often less than 100 cm deep.

Soil properties other then shrink-swell are the most likely determining factor in the predominance of grasslands on the Monaro. Clay contents are high and together with the composition of the clay result in a high soil water content value at wilting point (15 bar). This in turn limits the moisture available to plants and may be a driving factor in the dominance of grasses (Costin 1954). This is further supported by the presence of introduced tree species. Costin (1954) noted the introduced species *Populus alba* (white poplar) and *Salix babylonica* (weeping willow) grow well in poorly aerated soils and are successfully growing on the basalts of the Monaro Volcanic Province.

The low rainfall (450–600 mm per annum), severe frosts and desiccating freezing winds are all factors in the treeless nature of the Monaro basalts. But these factors must be considered in tandem with the soil properties. Soils developed on different geologies (granites and metasediments) but still within the lower rainfall areas of the Monaro Tableland have a low woodland to open forest growing on them.

In higher rainfall areas at the edge of the Monaro but still on basalt the soils and vegetation are different. Tantawanglo Mountain is a basalt outlier to the east of the Monaro Tableland. Rainfall is relatively high (> 900 mm) resulting in the development of Brown to Red Ferrosols (Krasnozems) in preference to the Brown Dermosols. In these areas a open forest is evident. Although climate generally determines the forest type on the basalt in these wetter areas it is the soil properties which have determined that forest exists in preference to grassland. Soil Moisture is more readily available to plants in the Red Ferrosols i.e. lower air dry moisture contents.

Climate, particularly rainfall, on the far North Coast is generally favourable for forest growth on most regolith types. The nature of a particular forest community is determined by rainfall, soil type and soil depth. Thus subtropical rainforest favours high rainfall with deep soils—these include but are not confined to the areas of Ferrosols formed on basalt. Dry rainforest and sclerophyll forest occur in locally drier areas on shallower soils—these also include those areas of basalt with shallower Dermosols.

The preponderance of forests on the far North Coast can be attributed to high rainfall, mild temperatures and the presence of deep, well drained soils derived from deep weathering of a thick volcanic pile. Although local changes in rainfall and soil type on basalt occur, from a regional viewpoint basaltic soils are deeper and climate conditions are markedly wetter and milder than those on the Monaro.

Earlier studies of the pedogenesis of basaltic soils in the Alstonville region of the far North Coast (Nicolls *et al.* 1953) noted that the 1500 mm isohyet marked the change from Ferrosols in the wetter east to Dermosols in the western areas, and therefore suggested that rainfall was responsible for basaltic soil differences. For the Monaro basalts a trend towards Ferrosols occurs at lower rainfalls. Although not as well developed as the North Coast Ferrosols the properties of the Monaro Ferrosols are sufficiently removed from the Brown Dermosols (Chocolate Soils) for open forest to have developed in preference to grassland. Such comparisons suggest, not surprisingly, that factors other than rainfall contribute to pedogenesis in both the Monaro and the far North Coast. Other instances of these 'soil/rainfall anomalies' exist - examples include Ferrosol formation in the Guyra area and Dermosol (Chocolate Soils, Alpine Humus Soils) formation in the wet Ebor area, both on the Northern Tablelands of New South Wales.

For the far North Coast broad vegetation communities appear to be a response primarily to climate, with local community variations being controlled by a combination of meso/microclimate and regolith. The reverse is true for the Monaro where the soils primarily determine if grassland or forest predominates. Local variations within these broad communities is then determined by a combination of meso/microclimate and regolith.

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