

# SOIL & REGOLITH PATTERNS AND NUTRIENT PROCESSES ACROSS AN ABRUPT WOODLAND-GRASSLAND ECOTONE

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## INTRODUCTION

It is generally accepted that the effects of climate, topography, disturbance regimes, biological activity and time interact to lead to the emergence of distinct ecosystem patterns at a variety of scales (Cumming & Elliot 1991, Gill 1994). Abrupt changes in environmental conditions lead to distinct boundaries and broad vegetation zones that conform to elevation contours, eventually leading to the upper treeline (Green & Osborne 1994, Costin *et al.* 2000). Similar patterns are observed in gentle to undulating subalpine valleys, especially in the northern end of Kosciuszko National Park, New South Wales. Here, distinct vegetation pattern inversions are seen leading into frost hollow grasslands, with abrupt boundaries between montane and subalpine eucalypt forests and woodlands, and *Poa-Themeda* tussock grassland (Wimbush 1967). These abrupt ecotones have been present for thousands of years, and consequently may also be reflected by small-scale patterns in soil and regolith physical and chemical properties in response to characteristic plant-soil interactions (Hamilton 1972, Hedenstroem 1993, Costin *et al.* 2000).

This research aimed to confirm and expand Hedenstroem's (1993) and Banks' (1997) findings of an abrupt soil chemical boundary, in calcium (Ca) and manganese (Mn) concentrations, across an inverted treeline on a gentle slope at Long Plain in Kosciuszko National Park. Specifically, this paper examines the role of the subalpine vegetation in developing patterns in the concentrations of Ca in the soils at an inverted treeline, on a steep slope. It will also seek causal relationships in the adjacent woodland and grassland ecosystems; to better understand the processes underlying the development of these patterns in soil chemistry.

## SITE ECOLOGY

The study site, situated across a woodland-grassland boundary on the western edge of Long Plain, can be located on the Tantangara 1:100,000 map sheet (#8626) using the Universal Grid Reference 55HFA418529 (AUSLIG 1999). A relatively uniform change in slope was observed at the ecotone. The steepest slopes (max slope = 28°) occurred near the woodland-grassland boundary.

The geology at the site is dominated by a spectrum of felsic volcanics and igneous rocks. The clay fractions in the rock samples were determined from XRD to include mixed interlayer clays, sericite, chlorite and kaolinite, with both goethite and gibbsite making up the opaques described in the thin-section descriptions. Geochemically, these rocks would contribute, in terms of those cations studied, Na and Mg but with relatively little Ca, Mn and P, and no N.

The soils at the site all keyed out as Paralithic Orthic Tenosols (Isbell 1994), Um7.11 and shallow or minimal Gn2.21 (Northcote 1971) or, Alpine Humus or Minimal Alpine Humus Soils (Stace *et al.* 1968). The associated erosion products from the steep hillslopes move with gravity and accumulate in the gentle valley, and so the soils there are deeper.

The abrupt contour-related vegetation boundary between woodland and grassland does not correspond with any known geological, soil or other landscape characteristics and is therefore assumed to be a result of periodic low minimum temperatures. Four obvious succession phases were observed across the ecotone. The open woodland was observed on the upper hill slope above an irregular but abrupt transition to a dense stand of regrowth *Eucalyptus pauciflora*, which in turn were above a diffuse lignotuber zone of the same species that extended for 15 m to 20 m beyond the inverted treeline. The climax *Poa-Themeda* grassland dominated the landscape below the treeline, characterised by the presence of *Themeda australis* tussocks.

## SPATIAL VARIATION AT THE ECOTONE

Distinct patterns were observed across a 60 m by 40 m spatial array, where samples were collected at 5 m intervals along transects set 10 m apart. The first patterns that became clear were that, as expected, leaf litter and its vegetative composition was at its deepest and most variable under the woodland, and a marked decrease in depth and a change in vegetative litter composition corresponded well with the woodland-grassland ecotone. These indicators of litter fall were somewhat associated with Electrical Conductivity (EC) and also with patterns observed in surface soil Ca concentrations.

On examining the patterns of total surface soil Ca, distinct boundaries were observed that corresponded with the woodland - grassland ecotone (Table 1). The abrupt ecotone is reflected by a similarly abrupt decline in total surface soil Ca concentrations, and is apparently unaffected by the steep slope at the woodland-grassland boundary. The pattern of surface soil Ca concentrations showed strong relationships with the total litter depth, the percentage of wood and bark in the fresh litter, and the EC in the A1 horizon, indicating that Ca is recycled through the woodland litter fall, and stem flow, or canopy throughfall and returned to the surface soils in very large quantities.

**Table 1:** Averaged surface soil properties across a *Eucalyptus pauciflora* woodland - *Poa-Themeda* grassland ecotone at Long Plain, Kosciuszko National Park, NSW.

	Variable Woodland 0 to 15 m	Regrowth 15 to 30 m	Lignotubers 30 to 45 m	Grassland 45 to 60 m
Ca ( $\mu\text{g/g}$ )	5,376	2,971	977	1,325
EC (A1 horizon ( $\mu\text{S}$ ))	49.7	59.2	47.6	51.2
pH (A1 horizon)	4.78	4.62	4.89	5.00
Litter Depth (cm)	6.3	5.3	2.1	1.3
Tree leaf litter (%Dry Wt)	26.1	28.1	8.0	0.0
Bark litter (%Dry Wt)	12.3	14.1	0.8	0.0
Wood litter (%Dry Wt)	34.2	33.0	3.5	0.0
Grass litter (%Dry Wt)	23.8	22.2	81.1	92.3

### ECOSYSTEM PROCESSES CAUSING SOIL PROPERTY PATTERNS

Three soil profile transects were established to examine the relationships between soil chemical properties and broad indicators of ecosystem processes like litter fall, stem flow and the activity of plant roots. Two 12 m long transects of soil profiles were sampled at 1 m intervals, between two *E. pauciflora* trees in the woodland and traversing *Poa* spp. and *T. australis* tussocks in the grassland. A third transect was 60 m long and crossed the ecotone at its mid point; samples were collected at 5 m intervals. The data collected along these transects helped to better explain the spatial patterns and associations observed in the surface soils across the woodland - grassland boundary.

**Table 2:** Averaged soil properties in soil profiles across an abrupt *Eucalyptus pauciflora* woodland - *Poa-Themeda* grassland boundary.

	Variable Woodland 0 to 15 m	Regrowth 15 to 30 m	Lignotubers 30 to 45 m	Grassland 45 to 60 m
A0 horizon Ca ( $\mu\text{g/g}$ )	4,758	3,819	1,248	Horizon absent
A1 horizon Ca ( $\mu\text{g/g}$ )	769	1,116	476	907
B horizon Ca ( $\mu\text{g/g}$ )	390	411	384	343
EC (A1 horizon ( $\mu\text{S}$ ))	49.7	59.2	47.6	51.2
pH (A1 horizon)	4.8	4.6	4.9	5.0
Litter depth (cm)	10.5	9.0	3.8	1.0
Tree leaf litter (%DWt)	25.0	37.1	17.6	0.0
Bark litter (%Dry Wt)	11.0	10.7	2.91	0.0
Wood litter (%Dry Wt)	30.0	22.3	13.8	0.0
Grass litter (%Dry Wt)	34.0	29.9	57.5	100

The soil profile examinations in the woodland and grassland showed that characteristic patterns develop in litter accumulation and composition, plant root distribution, EC and pH. In the case of the woodland, the patterns were centred about tree boles, and in the grassland patterns were observed in relation to the grass tussocks. These characteristically different patterns were, at least in part due to the different scale of interactions occurring in the two adjacent ecosystems. The distribution and chemistry of the plant roots, litter accumulation, and stem flow (broadly indicated by EC) in the woodland, were strongly associated with the total Ca concentrations, which accumulated in the surface soils nearest the trees and grass tussocks, and resulted in characteristically different patterns of this element in the soil profiles (Figure 1).

The soil profile transect that traversed the ecotone confirmed that the indicators of characteristically different nutrient cycles were reflected by an abrupt boundary in soil chemical properties at the location of the woodland - grassland boundary (Table 2).

### CONCLUSIONS

Two major conclusions were reached:

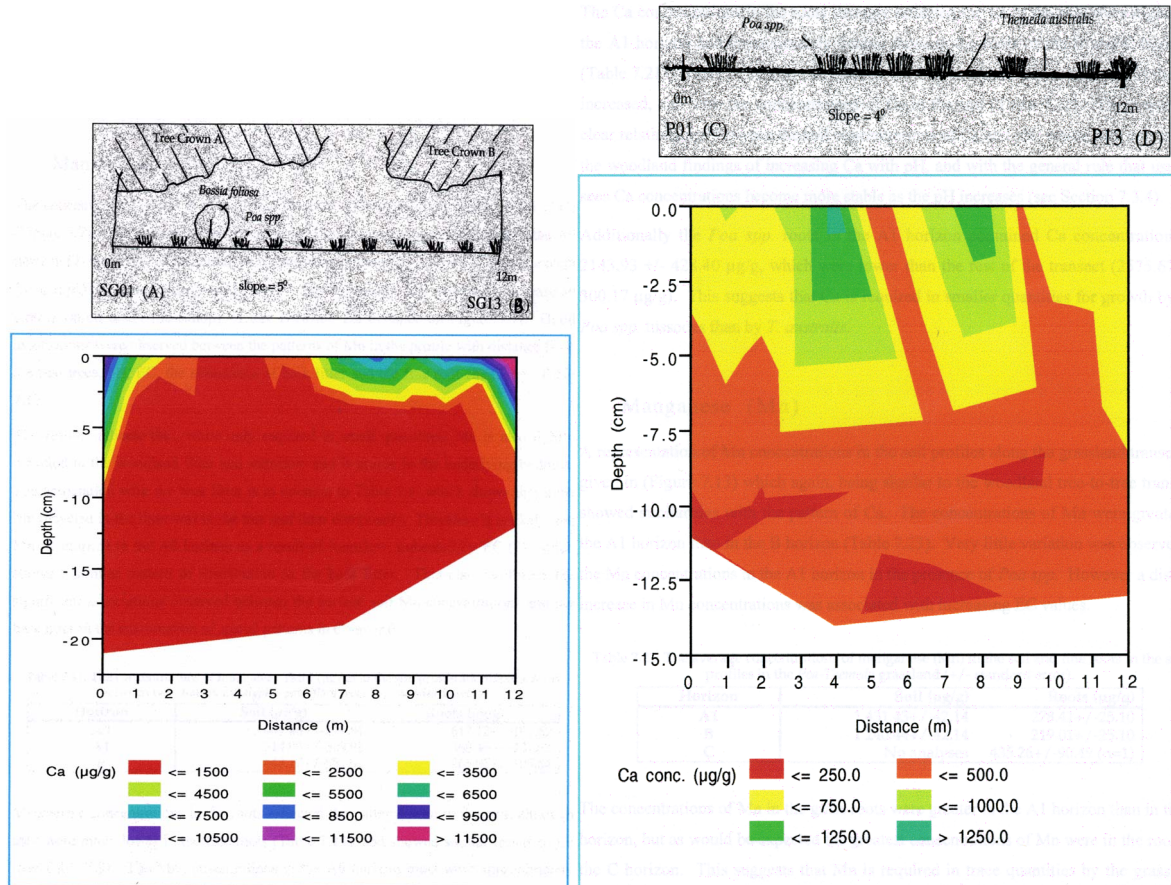
- An abrupt boundary was observed in surface soil Ca concentrations corresponding to the woodland-grassland ecotone, and was not affected by the steep slope across the ecotone; and,

- b) The soil profile patterns of total Ca concentrations indicated that, after being taken up from a parent material that is inherently low in Ca, it is recycled to the soil surface by litter fall, and possibly stem flow in the woodland.

To summarise, patterns in the surface soils under subalpine *Eucalyptus pauciflora* woodland and *Poa-Themeda* grassland reflected the location of the woodland-grassland ecotone, and were a reflection of characteristic nutrient cycling in the adjacent ecosystems. The trees in the woodland, and grass tussocks in the grassland, influenced the patterns in soil properties at a woodland-grassland boundary through processes such as litter fall and stem flow. Specifically, there were concentric patterns of Ca accumulation centred about trees in the woodland and grass tussocks in the grassland, which correlated well with concentric patterns of litter depth and composition, and EC. These process-related patterns in the surface soils also provide evidence that an important role is played by the vegetation in soil development. The results add to the findings of Hedenstroem (1993) and Banks (1997) of abrupt boundaries in Ca and Mn concentrations at an inverted treeline on a gentle slope at Long Plain. This research shows that the same is true at a nearby woodland-grassland boundary, this time on a steep slope.

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**Figure 1a:** Patterns of calcium accumulation ((g/g) at 1m intervals in soil profiles between two mature *Eucalyptus pauciflora* trees of different size (Tree A (0m) = 1.2m; Tree B (12m) = 0.8m dbh). **Figure 1b:** Patterns of calcium accumulation ((g/g) at 1m intervals in soil profiles traversing grass tussocks in the *Poa-Themeda* Grassland.