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TANTAWANGALO RESEARCH CATCHMENTS

1. SOIL VARIABILTY IN RELATION TO TERRAIN

BY

P.J. RYAN, R.D. WILLIAMS AND S.M. MACKAY

FORESTRY COMMISSION OF NEW SOUTH WALES

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P.J. Ryan [1], R.D. Williams [2] and S. M. Mackay [3]

[1] SOILS AND NUTRITION SECTION
[3] HYDROLOGY SECTION
WOOD TECHNOLOGY AND FORESTRY RESEARCH DIVISION,
[2] BULAHDELAH DISTRICT OFFICE,
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SUMMARY

Three small catchments were investigated within the larger Tantawangalo Creek catchment which is located on the southern tablelands of New South Wales, Australia. A survey was carried out to determine the variation in soil morphological, chemical and physical properties across the three catchments. To aid this survey, the area was stratified into five land elements all of which had a biotite granodiorite soil parent material.

Variation between catchments occurred in their size, distribution of land elements and hydraulic conductivity. None of these differences were large enough to indicate major discontinuities between catchments. There was more variation in soil properties between land elements than between catchments. Soil organic matter, exchangeable calcium and saturated hydraulic conductivity all varied between land elements across all three catchments.

Although Tantawangalo and Yambulla research catchments (70 km to the south) were both located on granitic parent materials, there were differences in mineralogy and geochemistry between the two parent materials. These differences have affected various soil properties and, indirectly forest vegetation between the two research sites.

INTRODUCTION

Tantawangalo Creek water supply weir provides domestic water for several coastal towns in southern N.S.W. including Candelo, Pambula and Merimbula. The catchment area is over 10,000 ha, 97% of which lies within Tantawangalo and Glenbog State Forests. Forests within the catchment contain high volumes of commercial timber which have been included in long term planning by the Forestry Commission of N.S.W. for a sustained yield of native timber from the Eden Native Forest Management Area (Forestry Commission of N.S.W., 1982).

Recognizing the high water values of the area, the Commission decided that special catchment protection procedures would be required for any timber harvesting operations and that the effects of this harvesting on soils and hydrology should be assessed before decisions are made on future management (Forestry Commission of N.S.W., 1983). For this reason, a research programme was commenced which included instrumentation of three small catchments within the larger Tantawangalo Creek catchment. These new experimental catchments are 70 km north of the six small catchments instrumented for the Yambulla study in 1977. Both studies are located on granitoid parent materials.

At the outset of the Tantawangalo study it was intended to complement hydrological results with some of the longer term information already available at Yambulla (Mackay and Cornish, 1982; Moore *et al*., 1986b; Olive and Rieger, 1987; Mackay and Robinson, 1987). It was decided that as a basis for this extrapolation, a detailed comparison of the two areas was necessary. A comparison of general characteristics is presented in Table 1.

In designing the Tantawangalo experiment, a further more general question arose. Under what circumstances should a full calibrated catchment experimental design be used to solve site specific management problems when a similar experiment already exists within the same region? Given the high cost of such experiments, a more economical approach may be to limit data collection at the new site and concentrate on extrapolation of results from the existing study. It is intended to address this question in future papers, while the present paper is necessarily confined to presenting detailed descriptions of the new catchments and comparing them with the Yambulla catchments.

The first aim of this paper is to ascertain the physical homogeneity of the Tantawangalo research catchments by quantifying and comparing their physical attributes; their size, terrain and soil variation, and selected soil hydrological properties. The null hypothesis is that there are no differences between the three catchments. Realistically this is seldom the case although a relative degree of uniformity would be desirable for experimental purposes. The second aim is to compare these characteristics with those of the longer-termed Yambulla research catchments. The final aim is to determine implications for the design of catchment protection procedures which will be used during the proposed logging of the experimental catchments.

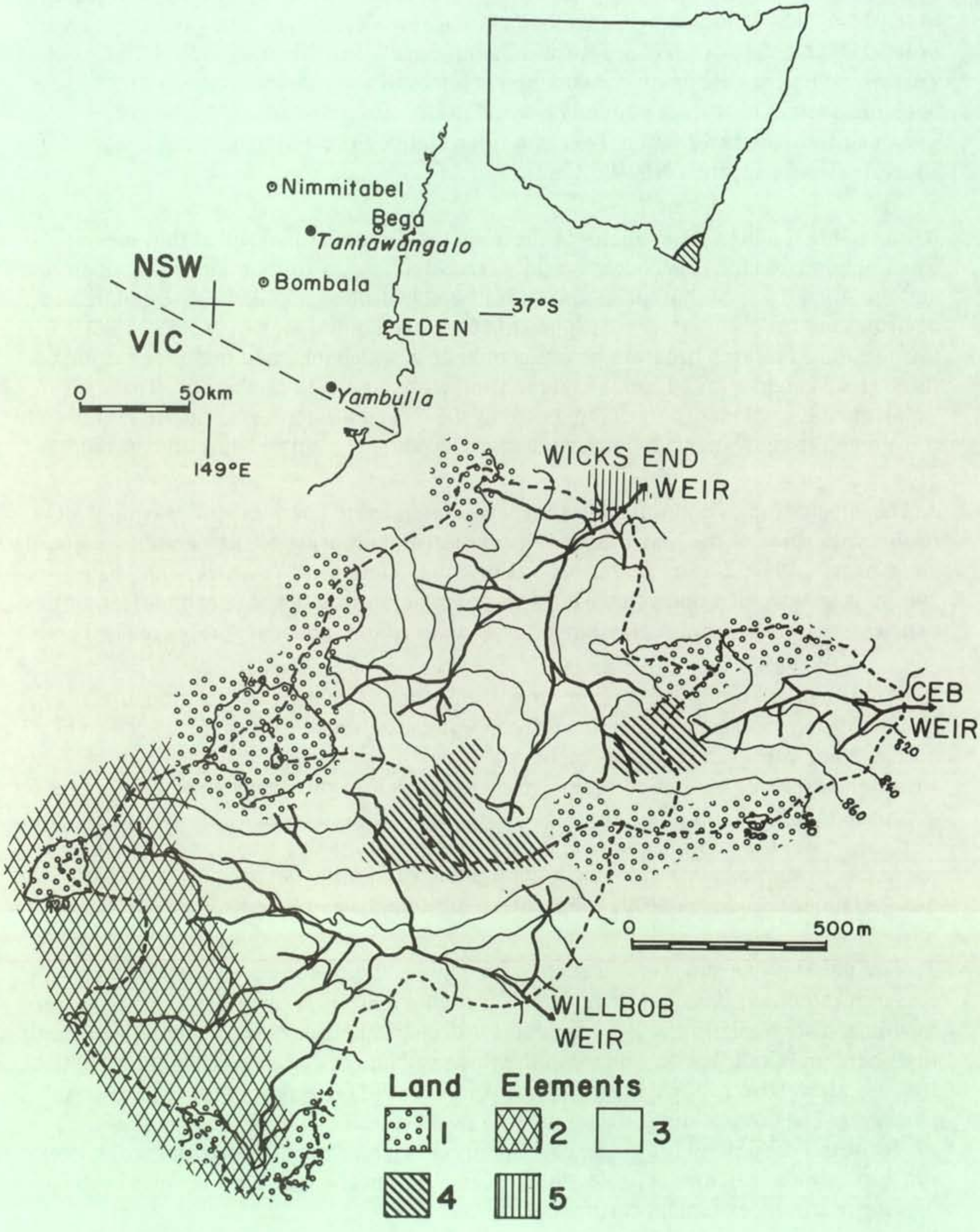

Figure 1. Location of Tantawangalo research catchments and the distribution of land elements across the catchments.

METHODS

1. Study Area

Location of Tantawangalo catchment and the research catchments is shown in Fig. 1. The area is an undulating plateau dissected by the north-south flowing Tantawangalo Creek. The research catchments are situated on three, east draining tributaries of Tantawangalo Creek, 32 km directly west of Bega. The plateau escarpment is only 3 km to the east of the weirs.

In 1984, three 'Crump' weirs were constructed on Ceb, Willbob and Wicksend Creeks. Flow recorders and automatic water sampling apparatus were installed at each weir site. Since 1984, runoff and water quality parameters have been monitored for all three catchments. This data set will be utilized for the hydrological calibration of the catchments.

2. Geology

The Tantawangalo research catchments are within the Bemboka Granodiorite; a large igneous intrusion outcropping over an area of 973 km^2 of which "the predominant rock type is a coarse, even-grained granodiorite/adamellite" (Beams, 1980). Variation occurs within the Bemboka Granodiorite element on an east-west axis. Specimens identified 2.5 km to the west of the catchments are mostly adamellites while specimens collected 9.5 km to the east are granodiorite (Beams, 1980).

Table 1. Comparison of site characteristics between Tantawangalo and Yambulla research catchments.

	Tantawangalo	**Yambulla**
State Forest	Glenbog	Yambulla
Location	36°41'S 149°29'E	37°29'S 149°35'E
Elevation range (m)	800 - 950	155 - 476
Geology (Beams, 1980)	Bemboka Granodiorite	Wallagaraugh Adamellite
Forest Type (Anon, 1989)	Brown barrel (154) Brown barrel/ messmate (155)	Silvertop ash (112) Silvertop ash/ stringybark (114)
Median annual rainfall (mm)	1 025[1]	837[2]
Mean annual runoff (mm)	394.6[3]	160
Total catchment area (ha)	175.5	667.8
Established	1984	1977

1 Mt. Darragh meteorological station.
2 Eden meteorological station
3 Data for Tant'awangalo weir, Department of Water Resources, N.S.W.

Table 2. Distribution of land elements between catchments at Tantawangalo and allocation of soil sampling sites within these areas.

Land Element	Description	Catchment								
		Ceb			Willbob			Wicksend		
		Area (ha)	Pits	Auger	Area (ha)	Pits	Auger	Area (ha)	Pits	Auger
1	Hillcrests with tor outcrops	5.3 (24.4%)	1	3	9.4 (11.0%)	2	7	10.3 (15.1%)	1	4
2	Upper slopes and ridges (low slope angles)	np[1]			33.5 (39.1%)	3	10	np		
3	Steep mid and lower slopes, tor outcrops	14.6 (67.3%)	1	6	39.0 (45.6%)	2	8	47.6 (69.8%)	1	4
4	Flat ridges-saddles (low slope angles), deep soils	1.8 (8.3%)	1	6	3.7 (4.3%)	1	4	9.9 (14.5%)	2	6
5	Footslopes, all-uvial benches, deep, leached soils	np			np			0.4 (0.6%)	1	5
	Total	21.7	3	15	85.6	8	29	68.2	5	19

1 Not present in this catchment

3. Vegetation

The forest overstorey in the three catchments is dominated by *Eucalyptus fastigata* (brown barrel) with *E. obliqua* (messmate stringybark) and *E. cypellocarpa* (monkey gum) as the main co-dominants. The forest typing of the catchments (Table 1) carried out according to Anon (1989), also lists these species as the prevalent overstorey.

The understorey varies from thickets of *Bedfordia arboresences*, *Pomaderris* spp and *Olearia* ssp. through dense mixtures of sedges (*Gahnia* spp.) and shrubs (*Acacia*, *Tasmanica* and *Bursaria* spp.), to an open shrubland with single species of *Exocarpus*, *Senecio* and *Goodenia*.

The ground cover varies from dense ferns (*Blechnum nudum*, *Polystchum* spp.) through scattered herbs and grasses (*Geranimum* and *Poa*). A more detailed investigation of vegetation variation within the research catchments is given in Dodson *et al*. (1988).

4. Land Classification and Soil Survey

To statistically assess variation in soil properties and vegetative cover between catchments would require an intensive sampling strategy (possibly on a grid system) plus subsequent exhaustive laboratory analyses. This was beyond the scope of this study so an alternative approach was chosen based on stratification of the area into landform units for which it was assumed soil variation was minimal compared with that between units. Such a stratification on landform facilitated the conceptual modelling of soil formation within a single parent material and thus allowed a practical programme of soil sampling to cover the full range of soil-landform variation within the research area.

Air photo interpretation (API) techniques were used to subdivide the three catchments into major landform elements as defined in McDonald *et al*. (1984). At least one soil profile and from 3 to 10 auger holes were excavated at random locations within each landform element present in each catchment (Table 2). A pit was abandoned if rock was struck at less than 0.3 m and another dug at a random bearing and distance. Site and soil morphology associated with each soil pit was described using the methodology of McDonald *et al*. (1984). Soil samples were taken at two standard depths (0-0.075 m and 0.30-0.38 m) together with selected horizons.

5. Laboratory Analysis

Soil samples were air-dried, ground, passed through a 2 mm sieve, the gravel fraction weighed, and the fine-earth fraction retained for analysis. Chemical analyses included pH (1:1 soil-solution ratios in water and 1 M KCl), total P and total N, exchangeable base cations, and organic matter. Physical analyses including particle size analysis and dispersion percentage (Bond *et al*., 1990) were determined by the Goulburn laboratories of the Soil Conservation Service of N.S.W. All other methodology was according to Lambert (1983).

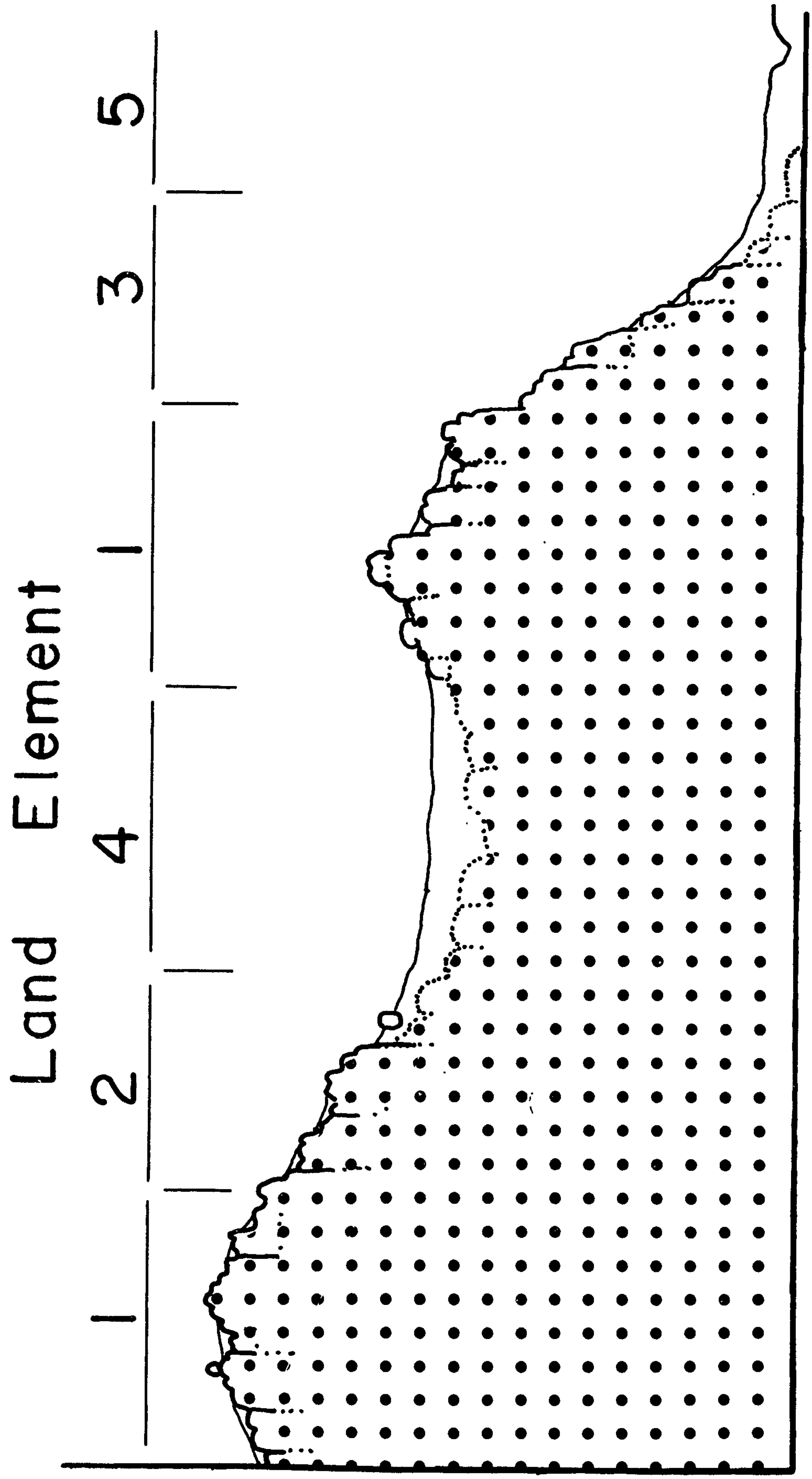

Figure 2. A diagrammatic representation of the relationship between landform and land element class at Tantawangalo research catchments.

6. Hydraulic Conductivity Measurement

Saturated hydraulic conductivities (K_S) were measured at three depths (soil surface at 0-0.1 m; 0.3-0.6 m; and 0.7-1.0 m). The measurement at the surface layer (0 - 0.1 m) was determined using large cores 0.3 m in diameter (Talsma, 1969) and at the other two depth intervals using the simplified well permeameter of Talsma and Hallam (1980). To enable comparison with earlier published values of K_S, the improved method of calculation suggested by Reynolds *et al.* (1983) was not used. These measurements were made in at least 4 and up to 14 random locations within each land element present in each catchmen

7. Statistical Analysis

For each soil depth, the hypothesis that single soil properties did not vary between either catchments or land elements was tested using one-way analysis of variance (ANOVA) (SAS Institute Inc. 1985). If any one-way ANOVA was found to be significant at P.05, treatment means were compared using the Student-Newman-Keuls test (SNK).

RESULTS

1. Landform

Relationships between land element type and catchment landform are shown in Fig. 2. Areas of each land element type within the three catchments at Tantawangalo are given in Table 2.

The three Tantawangalo catchments are not equal in area and do not contain an even distribution of the five land elements. Ceb catchment is approximately one quarter the size of either Wicksend or Willbob catchments. Land element 3 is the most ubiquitous of the land elements occupying 46 to 70% of the three catchments. Other land elements only occur in certain catchments; land element 2 covers 39% of Willbob catchment while land element 5 covers only 0.4 ha in Wicksend catchment. Table 2 also shows that for all three catchments there are relatively similar areas of land elements 1 (11% to 24%), land element 3 (46% to 70%) and land element 4 (4% to 15%).

Table 3 summarises the features of the soil profiles examined in the Tantawangalo survey and their classification using A Factual Key (Northcote, 1979) and Great Soil Groups of Australia (Stace *et al.,* 1968).

2. Soil Morphology and Classification

Tantawangalo catchment profiles are dominated by deep, red, sandy clay loam to clay B2 horizons over weathering granodiorite. Soil depths in land element 1 (hillcrests) were highly variable but with moderate solum development between granodiorite tors. Land element 4 (stable, flat ridges and saddles) had the deepest soils. Weak to moderate structure was evident in the B horizons in land elements 1 to 3. Earthy fabrics were most common in the deep soils of land element 4 .

Table 3. Selected soil morphological properties of profiles described in the Tantawangalo catchments.

Land Element	Catchment	Profile Number	Munsell Colour		Depth to		Field Texture[1]		Classification	
			A1 Hor.	B2 Hor.	B Hor. (m)	Subst. (m)	A1 Hor.	B2 Hor.	F.K.[2]	GSG[3]
1	Ceb	6	10YR3/3	7.5YR5/8	0.13	0.90	CL	LC	Gn4.81	RE
	Willbob	1	7.5YR3/2	5YR5/8	0.22	1.30	CL	MC	Dy4.21	RP
	Wicksend	11	10YR3/4	7.5YR5/8	0.29	1.20	L	CL	Gn4.8	RP
2	Willbob	13	7.5YR2/3	5YR5/8	0.30	0.90	L	LMC	Db3.21	RP
	Willbob	12	10YR2/2	5YR5/8	0.41	1.50	L	LC	Gn4.8	RP
	Willbob	9	10YR2/3	7.5YR4/6	0.29	1.00	CL	LC	Gn3.24	RP
3	Ceb	7	10YR2/2	5YR4/8	0.63	2.00	CL	LC	Gn4.14	RP
	Willbob	3	10YR2/1	7.5YR5/6	0.26	0.99	CL	LC	Gn2.24	BRE
	Willbob	10	7.5YR3/3	7.5YR5/6	0.16	1.00	L	LC	Gn2.21	RE
	Wicksend	8	10YR2/3	5YR4/6	0.18	1.30	L	LC	Gn3.14	RP
4	Ceb	14	7.5YR3/2	5YR4/8	0.40	1.90	CL	LC	Gn3.14	RP
	Willbob	15	7.5YR3/2	5YR4/8	0.20	1.50	L	SCL	Gn2.11	RE
	Wicksend	4	10YR2/2	5YR4/8	0.33	1.30	LC	LMC	Uf4.2	RE
	Wicksend	5	10YR2/3	5YR4/6	0.42	1.50	L	LC	Gn2.11	RE
5	Wicksend	2	10YR2/2	10YR5/4	0.46	1.20	LKS	MC	Db4.11	GBP

1 Codes are from McDonald *et al.* (1984): L, loam: LKS, loam (coarse sandy); CL, clay loam; SCL, sandy clay loam; LC, light clay; LMC, light medium clay; MC, medium clay.

2 The Factual Key (Northcote 1979)

3 Great Soil Group codes from McDonald *et al.* (1984): RP, red podzolic; RE, red earth; BRE, brown earth; GBP, grey-brown podzolic.

Munsell colours of the B2 horizon were consistently yellowish red or strong brown throughout land elements 1 to 4 (Table 3). Land element 4 soils have a generally redder hue and higher chroma in the B2 horizons indicating a higher degree of weathering and good drainage. Land element 5 soil was distinctive with a pale mottled B2. This profile was located on an alluvial bench above Wicksend Weir and had poor subsoil drainage as indicated by mottled B horizons.

3. Soil Chemical Properties

Variation in soil chemical properties at two standard depths across the catchments between land elements is summarised in Table 4. Note that land element 5 is not included in the ANOVA due to lack of occurrence in the other two catchments.

Significant differences were found for organic matter and exchangeable calcium between land elements in the surface soil. For both properties, levels were lower within land element 1 (hillcrests) and highest on either of the hill slope elements (2 or 3).

4. Soil Physical Properties

Soil textures estimated in the field varied from loam to clay loam in A1 horizons to sandy clay loam up to medium clay in B2 horizons (Table 3). Particle size analysis (PSA) confirmed these field results (Fig. 3), although there was a general over-estimation of clay content in the field textures for B horizons.

Fig. 3 shows that sand fractions dominated most horizons with most being in the coarse grades (20.8% to 69.4%). Prevalence of this latter fraction is a consequence of having a granodioritic parent material. Silt contents were all low (7.9% to 22.2%) with little variance with either soil depth or land element except for the higher surface soil levels within land element 4. Clay content in A horizons varied from 9.6% to 24.6% while for B horizons, clay ranged from 14.3 to 41.6%. These latter high clay contents were found only in the subsoils of land elements 1 and 4 and reflect their geomorphic stability. Fig. 3 depicts the relative uniformity in soil textural change with depth across land elements. There was a general slight increase in clay, fine sand, and a corresponding decrease in coarse sand content with soil depth for soils in land element 4.

The dispersion percentage determinations (Table 5) indicate the relative amount of unstable aggregates within the soil. Dispersion percentages were lowest (least dispersible) in A horizons for all land elements (5% to 8%). This would be due to the amount of organic matter in the surface horizons of these land elements (Table 4). Data for B horizons showed only slightly higher dispersibility (5% to 14%). Overall, these soils display little tendency to disperse.

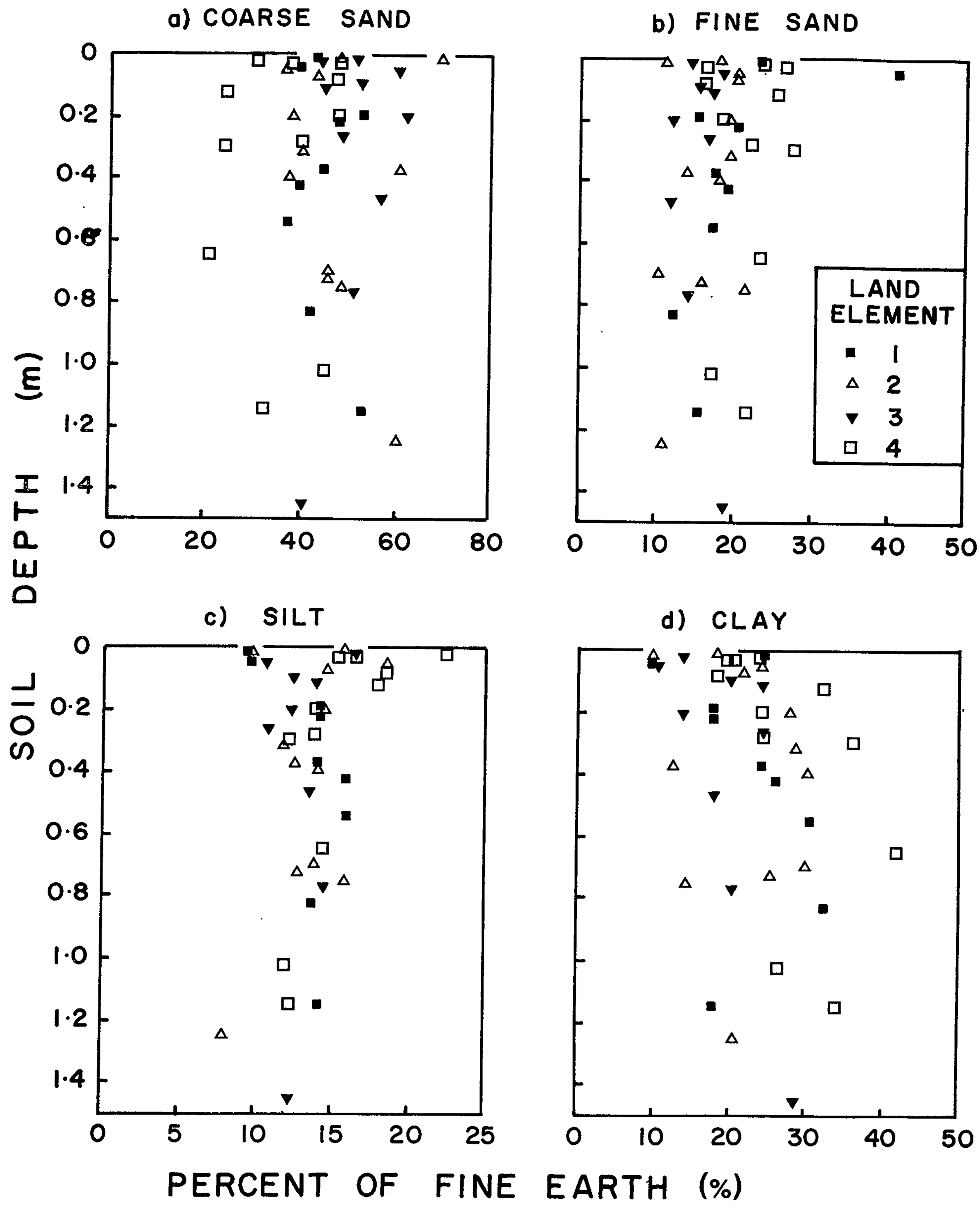

Figure 3. Particle size analysis of selected soil profiles within land element 1 to 4; a) coarse sand fraction, b) fine sand fraction, c) silt fraction, and d) clay fraction.

Table 4. Summarised soil chemical property data for all land elements. For land elements 1 to 4, one-way ANOVA were performed and if they were significant at P< 0.05 then means were compared using the Student-Newman-Keuls (SNK) test.

Soil Property	Depth Interval (m)	Land Element				Pr>F[1]	Land Element 5[2]
		1	2	3	4		
Sample Numbers	0-0.075	4	3	4	4		1
	0.30-0.38	4	3	4	4		1
pH (H_2O)	0-0.075	4.3	5.1	4.5	4.7	0.17	4.3
	0.30-0.38	4.4	4.7	4.4	4.5	0.45	4.5
pH (KCl)	0-0.075	3.9	4.7	4.2	4.1	0.34	4.1
	0.30-0.38	4.1	4.2	4.1	4.1	0.79	4.1
Total N (%)	0-0.075	0.15	0.20	0.32	0.26	0.13	0.33
	0.30-0.38	0.09	0.06	0.07	0.10	0.68	0.08
Organic matter (%)	0-0.075	5.00b[3]	6.56ab	9.41a	6.83ab	0.04	10.8
	0.30-0.38	2.73	2.02	1.91	3.35	0.54	2.73
Total P (ug g^{-1})	0-0.075	132	199	207	204	0.37	229
	0.30-0.38	129	132	122	128	0.99	99
Exch. Ca (cmol(+)kg^{-1})	0-0.075	1.55b	7.36a	5.95ab	2.44ab	0.03	5.73
	0.30-0.38	1.05	0.90	0.96	0.41	0.32	1.28
Exch. Mg (cmol(+)kg^{-1})	0-0.075	0.82	2.24	2.50	1.88	0.22	1.84
	0.30-0.38	1.02	0.92	0.86	1.31	0.82	0.65
Exch. K (cmol(+)kg^{-1})	0-0.075	0.58	0.73	0.92	0.85	0.42	1.29
	0.30-0.38	0.67	0.51	0.66	0.71	0.22	0.57
Exch. Na (cmol(+)kg^{-1})	0-0.075	0.08	0.08	0.11	0.09	0.63	0.14
	0.30-0.38	0.09	0.05	0.13	0.07	0.41	0.05

1 Probability that there is no difference between land elements for each soil property.
2 Land element 5 data not included in ANOVA due lack of replication.
3 Significantly different means as determined by the SNK test are indicated by different letter suffixes (e.g. a, b or c).

Table 5. Soil dispersion percentages for A and B horizons within land elements.

Land Element	Horizon	Dispersion Percentage (%)		
		Mean	Range	No.
1	A	6.03	0 - 9.1	4
	B	8.16	5.3-12.5	5
2	A	8.42	0 -15.4	6
	B	14.34	0-27.3	7
3	A	5.00	0- 8.3	6
	B	6.20	5.6-7.1	3
4	A	5.77	0-8.3	7
	B	5.28	4.3-6.7	4

5. Saturated Hydraulic Conductivity

Tables 6 and 7 present summary statistics for K_s values stratified by catchment and land element, respectively. Values in the surface 0.1 m of soil greatly exceed likely maximum rainfall intensities and were at least two orders of magnitude greater than values in the 0.3 m to 0.6 m and 0.7 m to 1.0 m depth intervals. Examination of surface soil cores and excavation of auger holes used for K_s determinations indicated preferential flow had occurred through macropores.

One-way ANOVA of the log transformed data categorized by either 1) catchment or 2) land element, for each depth interval indicated the importance of the impeded subsoil drainage in land element 5 which is present only in Wicksend catchment. Thus the 0.3 to 0.6 m K_s geometric means for Wicksend catchment were significantly lower (P 0.034) than the other two catchments. Similarly, when land elements were compared, both subsoil K_s geometric means were significantly lower in land element 5.

DISCUSSION

Classification of soils within the catchments produced little variation in soil type. Red earth and red podzolic great soil groups predominated on hill slopes and crests (Table 3). Where alluvium had accumulated in the small area of land element 5, increased leaching with impeded drainage produced a grey-brown podzolic soil. Using the Factual Key (Northcote 1979), the soils were classified into a diverse group of primary profile forms although the majority were acid earths with either structured or massive subsoils.

Chartres *et al.* (1988), Chartres and Walker (1988) and Walker *et al.* (1988) presented a detailed study of four granitic soils on hillcrests; one of which was on the Bega Batholith near Bemboka (on the coastal lowlands east of the research catchments). The Bemboka profile was a red podzolic (Udic Haplustalf). Evidence was presented by the above authors to indicate that all four granitic profiles, including the Bemboka soil, had received accessions of aeolian fine sand (62 to 31 μm).

Particle size analysis of the Tantawangalo soils, especially the hillcrests soils (Fig. 3), do not show any distinct accumulation of fine sand in the surface horizons although one hillcrest profile has a high fine sand fraction. Of more significance is the increase in the finer particle sizes (fine sand, silt and clay) in soils of land element 4. The relative geomorphic stability of these saddles and interfluves has allowed weathering of the coarse sand fraction into finer particles.

The Bemboka Granodiorite at the research catchments does not have the thick weathering mantle described for the Bega Batholith (Dixon and Young, 1981; Walker *et al.*, 1988) which is found directly to the east, on the coastal lowlands. This is primarily a function of differing mineralogy of the two granitic bodies as stated by Dixon and Young (1981) and supported by data of Beams (1980).

Across the catchments there is minor variation in soil chemical properties which can be related to variation in landform and soil morphology. This variation is however gradational and not indicative of major soil type or other environmental discontinuities.

Saturated hydraulic conductivity (K_s) values were log normally distributed and varied widely within catchments and within land elements, as found in other studies of forest soils (Talsma and Hallam, 1980). Low K_s values found in the subsoils of land elements 2 and 3 (Table 7) are not necessarily related to high clay contents because Fig. 3 shows that land elements 1 and 4 have higher clay levels in the B horizon. An alternative explanation is that the lower K_s readings at the 0.7 m to 1.0 m depth in the relatively shallow soils of land element 2 and 3 were due to positioning in the non-porous C horizon.

Comparison of Tantawangalo data with those from other granitic soils (Talsma and Hallam, 1980; Bonell *et al.*, 1983; Cassells *et al.*, 1985; Moore *et al.*, 1986b) indicated a broad similarity of results in at least the subsoil layers (Table 8). Tantawangalo and Bushrangers catchments (Talsma and Hallam, 1980) are the most similar. The high conductivities of the surface soils at the subtropical Babinda catchment were related to high biological activity in this layer under rainforest. None of the surface soils in the temperate catchments, including Tantawangalo, are as conductive.

Table 6. Variation in soil satuated hydraulic conductivity data within and between catchments.

Catchment	Depth Interval (m)	No. of Samples	Hydraulic Conductivity Statistics (mm hr^{-1})		
			Range	Mean	Geometric Mean
Ceb	0-0.1	14	324 - 1800	1029	918
	0.3-0.6	13	0.325 -17.08	5.151	3.19
	0.7-1.0	13	0.001 -18.47[1]	2.645	0.533
Willbob	0-0.1	25	10.80 - 3696	1206	805
	0.3-0.6	25	0.001 -126.7	10.8	1.425
	0.7-1.0	23	0.001 -141.9	14.1	0.654
Wicksend	0-0.1	16	286 - 3489	1123	876
	0.3-0.6	19	0.001 -32.03	3.501	0.257
	0.7-1.0	19	0.001 -17.14	2.520	0.365
Total	0-0.1	55	10.80 - 3696	1136	853
Catchment	0.3-0.6	57	0.001 -126.7	7.064	0.967
Area	0.7-1.0	55	0.001 -141.9	7.389	0.935

1 If no infiltration of water from the Talsma apparatus was detectable after 24 hr, then K_S was allocated the value of 0.001 mm hr^{-1}.

1. Comparison with Yambulla Research Catchments

How comparable then are the site and soils of Tantawangalo research catchments with those of the Yambulla research catchments, 70 km to the south?

In comparison with Tantawangalo, vegetation of the Yambulla research catchments is more diverse but less complex in structure; typically that of a dry sclerophyll forest. The overstorey is dominated by *E. sieberi* (silvertop ash), *E. agglomerata* (blueleaved stringybark) and *E. muellerana* (yellow stringybark) with occurrences of *E. consideniana* (yertchuk), *E. globoidea* (white stringybark), *E. obliqua* and *E. cypellocarpa*. Understorey is sparse and heath-like; consisting of species of *Epacris, Acacia, Banksia, Allocasuarina, Melaleuca*, and *Leptospermum* (Mackay and Robinson, 1987).

Wallagaraugh Adamellite at Yambulla has more K-feldspar and less plagioclase than Bemboka Granodiorite of the Tantawangalo catchments (Beams, 1980). Plagioclase in the Wallagaraugh Adamellite is more sodium rich than that found in the Bemboka Granodiorite. These differences are also important in understanding the nature of soil clay formed from these parent materials and their dominant exchangeable cations. Another important difference between the two parent materials is the amount of ferro-magnesium minerals.

These minerals also weather to clays but in the process produce sesquioxides in soil, which are important in flocculating clays and producing characteristic red soil colours. Data from Beams (1980) show that the granodiorite parent material associated with the Tantawangalo research catchments has the potential to produce more clay-rich, sesquioxide-rich soils and therefore inherently more stable soils than those formed from the Wallagaraugh Adamellite found at the Yambulla catchments.

Differences in the mineralogy and geochemistry of the Bemboka Granodiorite and the Wallagaraugh Adamellite are important in understanding the variation and contrast in soils (Kelly and Turner, 1978) and groundwater chemistry (Cornish, 1987; Cornish and Binns, 1987) found between Tantawangalo and Yambulla research catchments.

Moore *et al.* (1986a) described four soil types within one of the Yambulla catchments; a) uniform, coarse textured sandy soils (Uc1.22), b) yellow duplex soils (Dy2.71), c) yellow duplex soils (Dy3.11), and d) gley duplex soils (Dd3.11). This range of soil morphology, from uniform coarse sands to gleyed duplex soils within a single catchment is greater than that found over the total Tantawangalo catchment area and again reflects the different mineralogy and grain-size between the parent materials.

Soil chemistry of the Tantawangalo catchments can be compared with data presented by Kelly and Turner (1978) for soils on various parent materials in the Eden area. The two granitic parent materials surveyed by Kelly and Turner (1978) were Gabo Island Granite [Dgr] and Bega Batholith [Dgl]. The area of batholith sampled was mostly Wallagaraugh Adamellite with a number of soil samples taken within Yambulla State Forest (J. Turner *pers. comm.*). The soil chemistry in the Tantawangalo catchments was closer to that of

Table 7. Variation in soil satuated hydraulic conductivity data within and between land elements.

Land Element	Depth Interval (m)	No. of Samples	Hydraulic Conductivity ($mm\ hr^{-1}$)		
			Range	Mean	Geometric Mean
1	0-0.1	12	324- 2678	1266	995.5
	0.3-0.6	12	0.001-32.03[1]	10.20	2.426
	0.7-1.0	12	1.062-141.9	25.74	9.104
2	0-0.1	9	10.80- 1883	793.0	451.6
	0.3-0.6	10	0.001-33.50	4.703	0.350
	0.7-1.0	8	0.001-5.117	1.076	0.017
3	0-0.1	17	356- 3489	1189	995.5
	0.3-0.6	15	0.083-126.7	11.45	2.138
	0.7-1.0	16	0.001-20.35	2.463	0.556
4	0-0.1	15	285.7- 3696	1145	884.4
	0.3-0.6	15	0.421-13.21	4.085	2.422
	0.7-1.0	14	0.242-22.05	3.509	1.251
5	0-0.1	2	731.4- 2057	1394	1227
	0.3-0.6	2	0.001-0.192	0.042	0.005
	0.7-1.0	2	0.001-0.350	0.079	0.007

1 If no infiltration of water from the Talsma apparatus was detectable after 24 hr, then Ks was allocated the value of 0.001 mm hr-1.

[Dgr] than [Dgl]. Total phosphorus levels in subsoils at Tantawangalo were slightly higher than those for [Dgr] and double those for [Dgl].

Exchangeable sodium in Tantawangalo subsoils was at least half the levels in either [Dgr] or [Dgl]. These differences are mostly related to differences in mineralogy between the various granitic parent materials although, in the case of sodium, Tantawangalo is further from the coast than the sample sites for [Dgr] or [Dgl] and therefore receives less maritime salt input from rainfall.

Moore *et al.* (1986a) found that surface soils in the Yambulla catchments had very low clay contents of < 7% (except for the gleyed soils) and high sand contents (52% to 83%). Therefore it is surprising that Yambulla catchments had lower K_S values in the surface soil (Table 8), although the 0.3 m to 0.6 m value was greater than for Tantawangalo soil. The differences between the two catchments in their surface soil hydraulic properties probably reflect their different biological activities (Bonell *et al.*, 1983) rather than particle size variation.

There are therefore distinct differences in the two granitic soil parent materials at Tantawangalo and Yambulla research catchments and these have affected soil morphological, chemical and physical properties. Whether these differences are sufficient to affect the comparative hydrology and water quality will be addressed in a subsequent paper.

2. Implications for Catchment Protection Procedures

The main management implication of the variation in soil properties within the Tantawangalo Research Catchments is a recommendation for exclusion of land element 5 from harvesting operations due to its impeded drainage. Most of this land element would already be classified as streamside reserve and thus be exempt from any timber harvesting operation.

Land element 1 will have trafficability problems due the presence of tors. The relative uniformity of land elements 2, 3 and 4 offers few restrictions to timber extraction or problems with erosion control as long as streamside reservations are adhered to. Log landings could be located with minimal impact on land elements 1 or 4.

The combination of climate, forest type and soil nutrient regime at Tantawangalo will allow rapid revegetation of disturbed sites and this process should be facilitated wherever possible to minimise the period of increased run-off after harvesting operations.

Table 8. Comparison of mean and/or geometric mean hydraulic conductivity data (mm hr^{-1}) from Australian forested catchments. All sites are situated on granitic parent materials.

Depth Interval (m)	Tantawangalo		Yambulla[1]	Bulls Head[2]	Bushrangers[2]	Danbulla[3]		Babinda[4]	
	Mean	Geo Mean	Mean	Geo Mean	Geo Mean	Mean	Geo Mean	Mean	Geo Mean
0-0.1	1136	853	285	1066	1159			2733	2152
0.1-0.4								680	563
0.2-0.5						8.333	5.833	4.479	3.224
0.3-0.6	7.064	0.967	14.10	27.72	5.040				
0.5-1.0						3.333	2.500	1.458	1.021
0.7-1.0	7.389	0.935	4.933	5.760	0.930				

1 Moore *et al.* (1986b).
2 Talsma and Hallam (1980).
3 Cassells *et al.* (1985)
4 Bonell *et al.* (1983).

CONCLUSIONS

The three small hydrological research catchments within Tantawangalo Creek catchment area were all located on a biotite granodiorite parent material in an area that receives 1025 mm median annual rainfall. The area covered by each catchment varied from 21.7 ha (Ceb) to 85.6 ha (Willbob) and when stratified by landform class, no catchment had all land elements represented nor were there equal proportions of land elements within each catchment.

When soil physical properties were compared between catchments, the only significant differences were found for subsoil hydraulic conductivity due to the presence of one land element with impeded drainage in only Wicksend catchment. More variation in soil properties and vegetation could be discerned when the total area was categorized by land elements within a simple geomorphic model. Hillcrests (14% of the area) were characterised by *in situ* development of red podzolic soils between tors, low surface soil organic matter and exchangeable calcium, and subsoils with high hydraulic conductivities. Hill slope land elements (77% of the area) had mostly red podzolic soils with low subsoil hydraulic conductivities. Flat saddle ridges (9% of the area) had the deepest, most weathered soils (red earths) with the least dispersive subsoils, although these horizons had the highest clay levels. Alluvial-colluvial benches (0.02% of the area and in Wicksend catchment only) had distinctive duplex soils (grey-brown podzolics) with impeded drainage and very low hydraulic conductivities. *Eucalyptus fastigata* and *E. cypellocarpa* dominated the overstorey vegetation across all three catchments.

Yambulla catchments differed from those at Tantawangalo by having a) lower median annual rainfall and mean annual runoff, b) an adamellite parent material which has produced coarse-textured, duplex soils with low levels of phosphorus and high levels of exchangeable sodium, and c) an open dry sclerophyll forest characterised by *E. sieberi*.

Due to this land evaluation process, it is recommended that land element 5 be excluded from timber harvesting operations.

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