Relations of tree presence and topography to soil moisture levels across a montane valley, Bronte Park, Tasmania

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Abstract

This study investigates the possibility that an influential relationship exists between topography and tree presence on A horizon soil moisture levels across a montane valley in the Central Highlands of Tasmania. Field data was collected along a 600m transect with 10 x 10m quadrats at 10m intervals north and/or south of the transect. Two hypotheses were tested (1) that topography has an affect on A horizon soil moisture levels, and (2) that tree presence has an affect on A horizon soil moisture levels. Changes in surface land management practices affect subsurface conditions and with the global implications of land-clearing and climate change, soil moisture availability is becoming an increasingly important factor in natural resource management.

Existing literature indicates that both topography and tree presence affect soil moisture. This study however, found that soil moisture was not significantly affected by slope gradients along the transect. Analysis was conducted using Spearman's Rank Correlation Coefficient methodology which resulted in a positive correlation of 0.03.

The second hypothesis was tested using an independent t-test. The results indicate that there is a relationship between tree presence and soil moisture levels. Decreased soil moisture measurements were recorded where trees were present (mean = 18.555, standard deviation = 4.2181) compared to where trees were absent (mean = 22.184, standard deviation = 5.8992). This difference was not significant at 0.05 but was at 0.064 with a t value of 1.898.

The presence of trees affects soil moisture levels through transpiration and is relevant to determining land capacity qualities. The removal, inclusion or presence of trees will likely affect soil moisture levels in cool temperate montane environments and knowledge of soil hydrological processes is important as a factor in land use decision making, and for managing ecosystem functions.

Introduction

The Tasmanian Central Highlands bioregion features a high plateau with many montane valleys and a diverse range of vegetation communities. Communities include eucalypt open forests and woodlands, rainforests, grasslands, heath and other forest communities (Commonwealth of Australia, website viewed 10th April 2007). The montane environments of the central highlands provides a suitable environment for the study of soil moisture, topography and vegetation relationships due to the patchy occurrence of open eucalypt forest, sloping topography and various forms of grasslands. An understanding of these relationships is important not only for land capacity and natural resource management purposes but also for biodiversity conservation considerations.

In January 2007, A study along a transect in a montane valley near Bronte Park (Figure 1) in Tasmania's central highlands was conducted by the University of Tasmania Faculty of Science and Engineering. This paper draws on the results of these field studies and aims to describe the relational effects that exist between topography and tree presence to A horizon soil moisture levels.

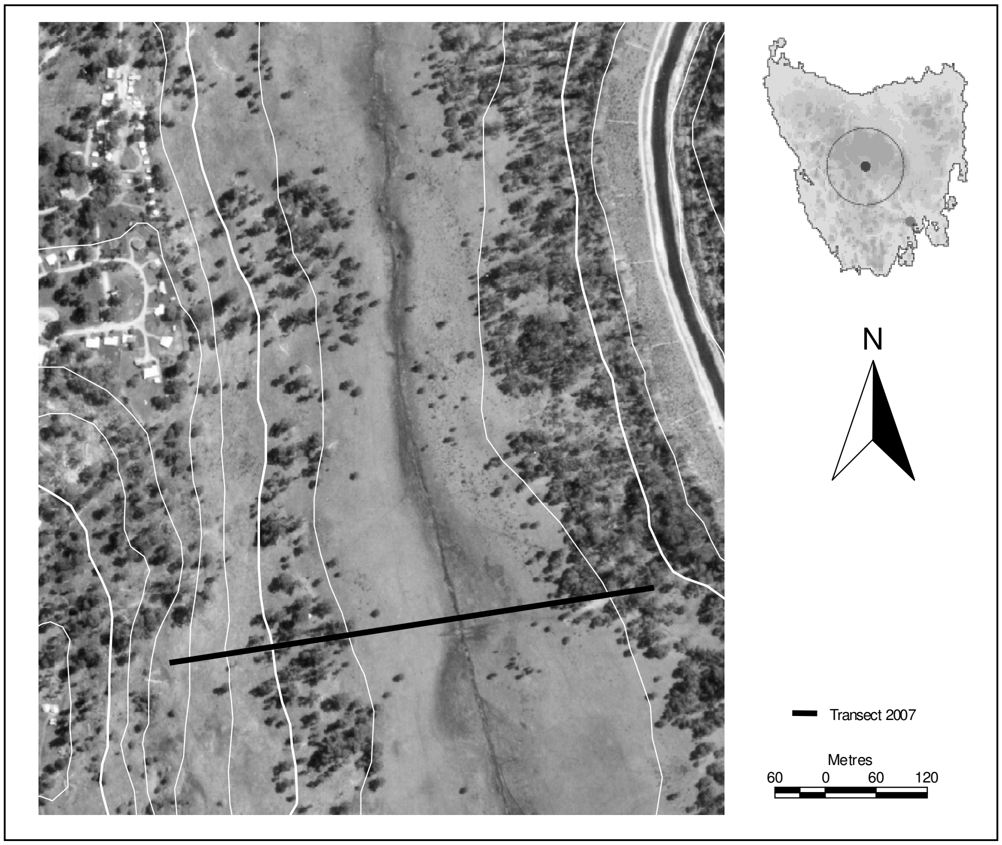

Figure 1 Aerial photograph showing transect, Bronte Park, Tasmania. Projection AMG, Datum AGD66. Aerial Photograph suppled by TASMAP and rectified by Dept. Geography & Environmental Studies using a DEM derived from contours supplied by Land Information System Tasmania.

Globally, many studies have been conducted on soil, topography and vegetation relationships with correlations indicating that these properties have a significant effect on soil properties (e.g. Miller et al. 1983, Oliveira-Filho et al. 1998, Van den Berg and Oliveira-Filho 1999, Wang et al. 2000, Mulungu et al. 2005). Ruggiero et al. (2002) found that in Brazil, clear distinctions based on soil properties could be made between forest and savanna physiognomies. They stated that vegetation and soil are 'intimately related' and that vegetation can influence nutrient flows to soils, and that plant species competition occurs primarily in the soil substrate. Also in Brazil, Oliveira et al. (2001) found that 'species abundance distributions were significantly correlated with the soil properties'. They assert that key factors determining tree species distributions were soil nutrient content and ground water regimes.

Chen et al. (1997) found that landscape-scale aspect/soil relationships rather than vegetation/soil relationships were a stronger factor in determining soil/aspect/vegetation matrix composition. They further assert that 'differences in soil properties attributed to the influence of the occupying vegetation can be detected even under the strong effects of topographic factors'. In addition, it has been found that vegetation species distribution strongly correlates with soil properties and drainage systems (Bourgeron 1983 and Johnston 1992, cited in Chen et al. 1997).

The influence of forests and individual trees on soil water levels was investigated by Ziemer (1981) who claims that forests 'remove considerable quantities of soil moisture by evapotranspiration', it was also found that the influence of a single tree on localised soil moisture levels extends significantly beyond the root biomass.

Research in southwestern Australia woodlands indicates that soil surface strongly influences water capture and retention, resulting in increased localised infiltration, uptake and use (Hobbs and Cramer, 2003). Pate and Bell (1999 cited in Hobbs and Cramer, 2003) assert that overstory qualities also affect below-ground structures and that overstorey diversity and structure composition between and within patches perform important functional roles, particularly for water capture and use.

There is a limited amount of available research on Tasmanian soil/topography/vegetation relationships. Laffan (1997) asserts that in Tasmania existing vegetation types can indicate soil moisture, particularly where topography is a factor. Laffan et al. (1995) describe qualities affecting soil moisture availability as including native vegetation cover and that soil composition and processes are affected by many factors including topography.

It is hypothesized that influential relationships exist between topography and tree presence on soil moisture levels along the transect. Two hypotheses will be tested (1) that topography has an affect on A horizon soil moisture levels, and (2) that tree presence has an affect on A horizon soil moisture levels. With the implication of land clearing as an agricultural practice and the potential for changing climate and rainfall patterns, soil moisture availability is becoming an increasingly important factor in land management. This paper aims to highlight the relational significance of topography and tree presence on soil moisture levels in a specific Tasmanian context.

Methods and materials

Study site

The study was carried out in a montane valley at Bronte Park, Tasmania, Australia. Regional climate is cool temperate with a mean annual rainfall of 894.6mm with the wettest month being August at 97.5mm over 18.1 days and the driest being February with 53.1mm over 8.9 days. Mean minimum temperature is 3.4°c with the coldest month being July at 0°c. Mean maximum temperature is 13.9°c with the warmest month being February at 20.4°c (Bureau of Meteorology, 2007). Snowfall can occur throughout the year.

The valley features a central water filled trench running approximately north-south and a second larger water filled trench with an embankment to the east at the base of a hillslope. Talus is located along sections of the base of the eastern embankment and hillslope. In places footslopes and swamps extend to the central trench. On the valley's western side is another hillslope featuring evidence of landslides and alcoves as well as displaying bench formations and scarps with a plain below extending to swamps near the central trench. The study site is used primarily for sheep grazing.

Geology and soils

The valley is situated in the Nive River Land System which features 'terraced slopes of Tertiary basalt flows' (Land System Report 682321, DPIW). The geology of the study area is a mixture of Jurassic dolerite in the upper elevations of the valley, Triassic sandstones and mudstones along the lower hillslopes, and Quaternary swamp marsh and alluvial deposits along the valley floor (Figure 2) providing regolith that forms the basis of soil catenas. Soils within the Nive River Land System are loamy along terraces and river flats, with swampy areas featuring light clays overlaid by peat and lower slopes featuring black soils (Land System Report 682321, DPIW).

Soils along the transect predominantly featured sandy loam AO and A horizons overlaying clay B horizons. Mean average pH level was 5.8, with the lowest pH readings being 4, and the highest 6.5. Mean average soil moisture along the transect on Monday 22nd January was 22.47%.

Figure 2 Geology of Bronte Park area showing transect.

Vegetation

Vegetation along the transect was comprised of 58% *Poa* grasslands, dominated by *Schoenus spp., Juncus spp., Poa spp.,* and the exotic *Agrostis spp.*; 17% of the transect was *Eucalyptus rodwayii* dominated woodlands with a single occurrence of *E. pauciflora* at the eastern end of the transect (pegs 580 – 590) and an understorey dominated by *Danthonia spp., Schoenus spp., Carex longebrachiata* and the exotic *Agrostis spp.*; 14% was open *E. rodwayii* forest with an understorey dominated by *Schoenus spp.* and *Poa spp.*; 9% was shrubland dominated by *Agrostis spp*. and featuring *E. rodwayii*; and, 2% was sedgeland dominated by *Poa spp.* and the exotic *Holcus lanatus*.

Transect description

A 600m long transect (see Figure 3 and Figure 3) was established between AGD 66 Zone 55 5334357N, 458148E at 670.981m elevation and 5334439N, 458716E at 641.437m, with the lowest point being the trench at 5334409N, 458491E at an elevation of 631.645m above mean sea level. Marker pegs were installed every ten metres along the transect.

Topography is indicated by elevation gradients measured with dumpy levels (checked for collimation error using the two peg test) using the rise and fall reduction method to obtain slope characteristics along the transect (Figure 3). Slope classes as defined by McDonald et al. (1990, cited in Laffan et al. 1995) range from flat (<1%) to rolling (10-30%) with a mean average undulating slope (3-10%).

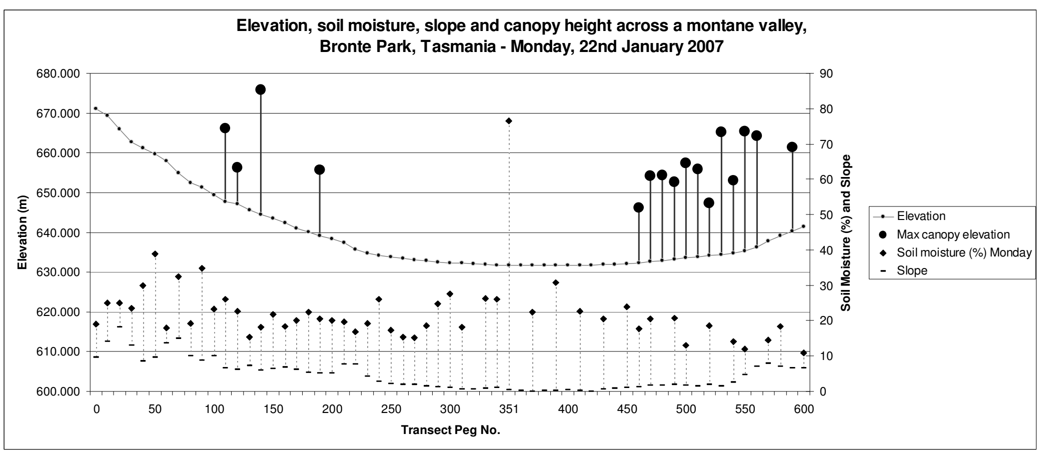

Figure 3 Elevation, soil moisture, slope and canopy height along the transect.

A horizon soil moisture (%) was measured using Theta soil moisture probes at marker pegs on Monday 22nd January, 2007.

The presence of trees was determined by creating 10 x 10m quadrats between peg markers and immediately north and/or south of the transect. Various observations and measurements were conducted within these quadrats including measures of tree height, basal area, canopy cover, tree density and stocking, and species identification. For the purposes of this study tree presence (sapling to senescent stages) or not was sufficient.

Data analysis

Soil moisture/slope gradient data was analysed using Spearman's rank correlation coefficient methodology to determine the relationship significance between variables and tested using Hood's (2006) permutation method. Spearman's rank correlation coefficient (ρ) is given as:

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

where:

d_i = the difference between each rank of corresponding values of x (soil moisture rank) and y (slope rank), and
n = the number of pairs of values.

The independent t-test was applied to the soil moisture/tree presence data to compare the statistical significance of the null hypothesis. The formula for the independent t-test is:

$$t = \frac{X_1 - X_2}{\sqrt{\left(\frac{SS_1 + SS_2}{n_1 + n_2 - 2}\right)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

where:

X_1 is the mean for group 1 (soil moisture where trees are present),
X_2 is the mean for group 2 (soil moisture where trees are absent),
SS_1 is the sum of squares for group 1,
SS_2 is the sum of squares for group 2,
n_1 is the number of subjects in group 1, and
n_2 is the number of subjects in group 2.

Quadrats with missing tree presence data and the water-filled trench data was omitted from the analysis as they were considered to skew the results.

Results

Soil moisture and slope

Applying Spearman's Rank Correlation Coefficient analysis to the soil moisture/slope gradient data resulted in a negative coefficient of -0.01 as indicated in the equation:

(ρ) = 1 – (126276/124950) = -0.010612245

The low correlation was assumed to result from the influence of the tree presence variable on soil moisture and a second calculation was conducted with the soil moisture readings under trees removed from the data set. As key data regarding tree presence was missing from between marker pegs 150 and 190, where trees were observed to be present, this data cohort has also been removed. The existence of a water filled trench at peg 351 also skewed the results and was omitted from the data set (see Appendix Table 1).

This second calculation therefore resulted in the equation:

$(\rho) = 1 - (37893/39270) = 0.03506493506$ or a positive correlation of 0.03.

The resulting low positive correlation indicates that greater slope gradients do not influence soil moisture levels along the transect in a significant way. A permutation test as per Hood (2006) was then performed and confirmed that there is no significant relationship between soil moisture levels and slope. These results however, may be affected by seepage from the eastern trench and further tests are required to determine levels of noise resulting from this source of moisture.

Soil moisture and tree presence

The results of the independent t-test confirm that there is a distinct relationship between tree presence and soil moisture levels (Figure 4). Decreased soil moisture measurements were recorded where trees were present (mean = 18.555, standard deviation = 4.2181) compared to where trees were absent (mean = 22.184, standard deviation = 5.8992) (see Appendix Table 2). This difference was not significant at 0.05 but was at 0.064 with a t value of 1.898 (see Appendix Table 3).

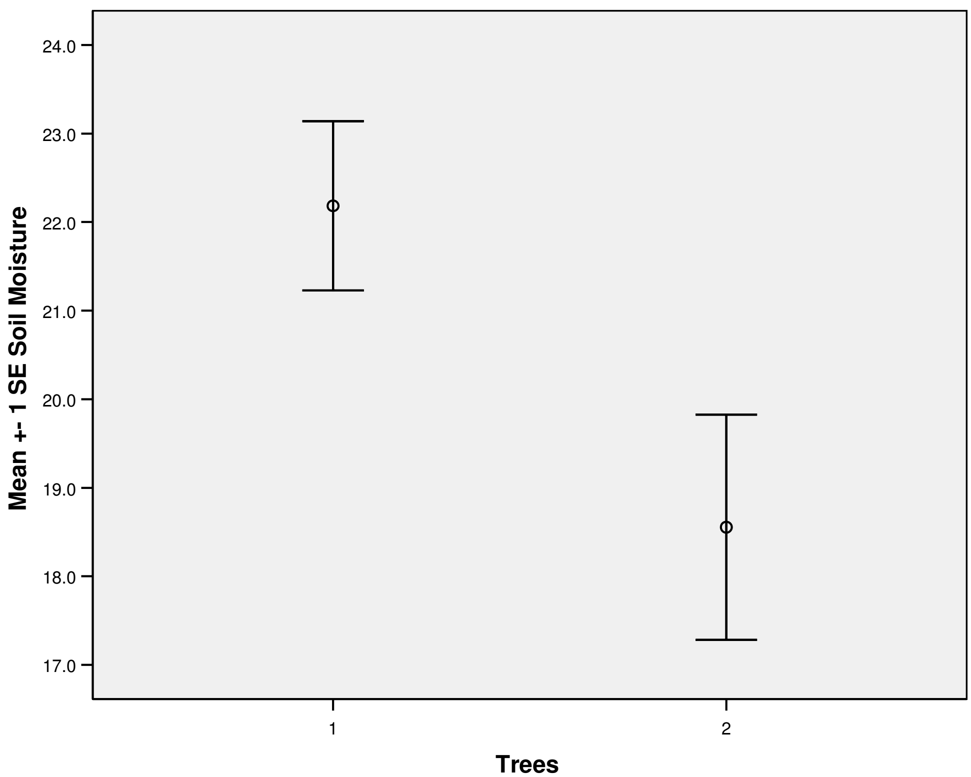

Figure 4 Mean average of soil moisture and tree absence (1) or presence (2) showing the standard error mean.

The analysis results may contain statistical errors derived from operator measurement error or bias, or as a result of incomplete data. The tests as applied in this study have attempted to reduce these factors.

Discussion

Variables affecting transect soil moisture qualities beyond the scope of this study are likely to include seepage from the eastern trench, insolation and canopy cover, soil structure, profile and morphology, catenas, consistence, permeability, and plasticity. It is likely that these variables will affect soil moisture both individually and collectively and as such these variables warrant further study.

The lack of a significant relationship between slope and soil moisture is not supported by the literature. Existing research indicates that topography is a key factor contributing to soil moisture properties (Miller et al. 1983, Jenny 1994, Mulungu, 2005, Sharma et al. 2006). It is possible that soil catenas play a more significant role in soil moisture properties than slope, or that the insufficient data did not enable adequate analysis. Other forms of analysis may also be of greater relevance in testing this hypothesis.

The influence of tree presence on soil moisture levels has implications for revegetation of cleared landscapes as the impact on soil moisture levels is significant and may alter biodiversity levels.

The need to understand the ecosystem functions matrix and pedotransfer qualities is essential to enable better land management and conservation decisions. Future research on soil moisture would benefit from taking a whole-of-system approach to better understand the relational affects of changes to ecosystem balances and resulting system adaptations.

Conclusion

Of the two hypotheses tested it was discovered that transect topography did not have a significant affect on soil moisture levels and therefore the first hypothesis was rejected. This unexpected outcome is possibly the result of other variables – particularly soil catena profiles, or gaps in the data, or the analysis method. Further study and analysis rectifying these shortfalls is required.

The second hypothesis, that tree presence affects soil moisture was found to be correct. The uptake of available water within the A horizon by trees is evident from the results. This reduction in soil moisture is likely to be the result of transpiration by trees and extends beyond the root zone affecting the broader ecosystem and landscape functions.

The results of this study indicate that land management practices should consider the affect that changing arboreal characteristics will have on A horizon soil moisture levels. Arboreal changes within a landscape are likely to affect land use and production capacity, as well as biodiversity values and ecosystem processes.

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Appendix

Table 1 Data used for correlation analysis.

Data for Spearman's rank correlation coefficient without soil moisture under trees or trench readings

Peg	Soil moisture (%)	Rank (x)	Slope	Rank (y)	Difference between ranks (d)	d^2
370	22.4	17	0.0	34	-17	289
410	22.6	16	0.1	33	-17	289
390	30.7	4	0.3	32	-28	784
310	18.2	26	0.7	30.5	-4.5	20.25
430	20.5	18	0.7	30.5	-12.5	156.25
330	26.4	7	0.9	29	-22	484
300	27.6	6	1.0	27.5	-21.5	462.25
340	26	8.5	1.0	27.5	-19	361
450	24	13	1.1	26	-13	169
290	24.7	12	1.4	25	-13	169
280	18.7	24	1.5	24	0	0
260	15.4	30.5	1.8	23	7.5	56.25
270	15.1	32	1.9	22	10	100
250	17.4	28	2.2	21	7	49
240	26	8.5	2.8	20	-11.5	132.25
230	19.2	21.5	4.2	19	2.5	6.25
200	20.2	19	5.1	18	1	1
600	11	34	6.7	17	17	289
580	18.3	25	7.1	16	9	81
130	15.4	30.5	7.2	15	15.5	240.25
210	19.7	20	7.6	14	6	36
220	16.9	29	7.7	13	16	256
570	14.5	33	7.9	12	21	441
40	30	5	8.5	11	-6	36
90	34.8	2	8.7	10	-8	64
50	39	1	9.6	9	-8	64
0	19	23	9.7	8	15	225
100	23.3	15	10.1	6.5	8.5	72.25
80	19.2	21.5	10.1	6.5	15	225
30	23.5	14	13.1	5	9	81
60	17.9	27	13.6	4	23	529
10	25	10.5	14.2	3	7.5	56.25
70	32.6	3	15.1	2	1	1
20	25	10.5	18.1	1	9.5	90.25
						6315.5

Table 2 Independent t-Test analysis of soil moisture and tree presence relationships: group statistics.

	Trees	N	Mean	Std. Deviation	Std. Error Mean
Soil Moisture	Absent (1)	38	22.184	5.8992	.9570
	Present (2)	11	18.555	4.2181	1.2718

Table 3 Independent t-Test analysis of soil moisture and tree presence relationships.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Soil Moisture	Equal variances assumed	1.301	.260	1.898	47	.064	3.6297	1.9119	-.2165	7.4759
	Equal variances not assumed			2.280	22.573	.032	3.6297	1.5916	.3337	6.9257

References

Bureau of Meteorology (BOM). 2007. <http://www.bom.gov.au/climate/averages/tables/cw_096002.shtml>, viewed 10 April 2007. Bureau of Meteorology.

Chen, Z., Hsieh, C., Jiang, F., Hsieh, T. and Sun, I. (1997). Relations of soil properties to topography and vegetation in a subtropical rain forest in southern Taiwan. Plant Ecolgy 132: pp. 229, 238, and 239 – 240.

Commonwealth of Australia. National Land and Water Resources Audit: Major vegetation groups and their status in each state and territory – Tasmania. <http://audit.ea.gov.au/anra/vegetation/docs/Native_vegetation/nat_veg_tas.cfm> viewed 10 April 2007.

Department of Primary Industries and Water (DPIW). Land System Report 682321: Nive River. Department of Primary Industries and Water, Tasmania.

Hobbs, R. and Cramer, V. 2003. Natural ecosystems: Pattern and process in relation to local and landscape diversity in southwestern Australian woodlands. Plant and Soil 257: pp. 371, and 373 – 374.

Hood, G. PopTools version 2.7.5. URL http://www.cse.csiro.au/poptools

Jenny, H. 1994. Factors of soil formation: A system of quantitative pedology. Dover Publications, New York. p. 15.

Laffan, M. 1997. Site selection for hardwood and softwood plantations in Tasmania: A methodology for assessing site productivity and suitability for plantations using land resource information. Soils Technical Report No. 3 Second Edition. Forestry Tasmania and Forest Practices Board, Tasmania. p. 8.

Laffan, M., Grant, J. and Hill, R. 1995. Soils of Tasmanian State Forests. 1. Pipers Sheet. Soils Bulletin No. 1, Forestry Tasmania. pp. 18 and 21.

Miller, P. C., Poole, D. and Miller, P. M. 1983. The Influence of Annual Precipitation, Topography, and Vegetative Cover on Soil Moisture and Summer Drought in Southern California. Oecologia 56: pp. 385 – 391.

Mulungu, D., Ichikawa, Y. and Shiiba, M. 2005. A physically based distributed subsurface-surface flow dynamics model for forested mountainous catchments. Hydrological Processes 19: pp. 3999 – 4022.

Oliveira-Filho, A., Curi, N., Vilela, E. and Carvalho, D. 1998. Effects of canopy gaps, topography and soils on the distribution of woody species in a central Brazilian deciduous dry forest. Biotropica 30: pp. 362 – 375.

Oliveira-Filho, A., Curi, N., Vilela, E. and Carvalho, D. 2001. Variation in tree community composition and structure with changes in soil properties within a fragment of semideciduous forest in south-eastern Brazil. Edinburgh Journal of Botany 58 (1): pp. 139 – 140.

Ruggiero, P., Batalha, M., Pivello, V., and Meirelles, S. 2002. Soil-vegetation relationships in cerrado (Brazillian savanna) and semideciduous forest, Southeastern Brazil. Plant Ecology 160. pp.1 – 2.

Sharma, S., Mohanty, B. and Zhu, J. 2006. Including Topography and Vegetation Attributes for Developing Pedotransfer Functions. Soil Science Society of America Journal 70 (5): pp. 1430 – 1440.

Van den Berg, E. and Oliveira-Filho, A. 1999. Spatial partitioning among tree species within an area of tropical montane gallery forest in south-eastern Brazil. Flora 194: 249 – 266.

Wang, Y., Kasischke, E., Bourgeau-Chavez, L., O'Neill, K. and French, N. 2000. Assessing the influence of vegetation cover on soil-moisture signatures in fire-disturbed boreal forests in interior Alaska: modelled results. International Journal of Remote Sensing 21 (4): pp. 689 – 708.

Ziemer, R. (1981). The role of vegetation in the stability of forested slopes. International Union of Forest Research Organisations. XVII IUFRO World Congress Proceedings, Division 1. p. 304.