Forest soils derived from granite in northern Tasmania: an overview of properties, distribution and management requirements

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Abstract

Granitic rocks cover a large area in northern Tasmania, occurring as a number of discrete blocks from Trial Harbour in the west to Freycinet Peninsula in the east. The granitic rocks are mainly of Devonian age and include adamellite, granite and granodiorite. They occur in association with granite-derived alluvial sediments of Tertiary and Quaternary age.

Climate varies widely over the granitic rocks resulting in a diverse range of vegetation and soil types. On a broad scale, the properties and distribution of the soils show close links to the distribution of major native forest types. Texture-contrast soils, characterised by coarse sandy and gravelly surface layers overlying clayey subsoils, predominate under dry forest types whereas gradational soils, characterised by loamy topsoils overlying clayey subsoils, are generally associated with wet forests. Texture-contrast soils have low levels of nutrients and high or moderate to high erodibility. In contrast, gradational soils under wet forest types have medium to high levels of nutrients and low to moderate erodibility.

On a detailed scale, the soil pattern is more complex and, since soil mapping commenced in 1990, 30 soil-profile classes and variants have been differentiated based on inherent soil properties, parent material and native vegetation type. Management requirements vary widely and are dependent on soil properties. This paper outlines the distinguishing features of the soil-profile classes (and variants) and summarises their major properties and the management practices required for their sustainable use.

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Introduction

Granitic rocks are igneous rocks formed deep in the earth's crust and composed largely of quartz, feldspar and coloured minerals, usually biotite. They cover a relatively large area in northern Tasmania, occurring as a series of discrete blocks from King Island and Trial Harbour in the west to Flinders Island and Freycinet Peninsula in the east. The largest single block of granitic rocks occurs in the north-east between Mt Barrow and St Helens. The granitic rocks are mainly of Devonian age and include adamellite, granite and granodiorite. They occur with Tertiary and Quaternary sediments derived from these rock types. In granite, orthoclase feldspar is dominant over plagioclase, whereas in granodiorite, plagioclase predominates. Adamellites may have equal proportions of both feldspars and, in Tasmania, they have been mapped at 1:50 000 scale as separate units or as complexes with granite or granodiorite.

Photo 1. Severe gully erosion in sandy soils formed on Quaternary alluvial deposits derived from granite (Albion soil-profile class) near St Helens.

The granitic rocks occur under a wide range of climates resulting in a diverse range of soils and vegetation types. The properties and distribution of the soils are strongly correlated with the distribution of the major native vegetation communities. Eucalypt forest is the dominant native vegetation but there are also extensive areas of rainforest and sedgeland-heathland. The soils derived from granite support a major resource of wet eucalypt forest which produces high quality sawlogs and other wood products. The granite soils in high rainfall areas are also highly suitable for intensive production under plantations.

The diversity of forest soils occurring on granite requires a corresponding range of management techniques. For example, coarse sandy soils formed on Quaternary alluvial deposits derived from granite under dry open forest near St Helens are very highly erodible and have very low levels of nutrients and low water-holding capacity. Such soils are highly susceptible to sheet and gully erosion and are also very drought-prone (Photo 1). They are unsuitable for plantations because of very low productivity and the high risk of erosion. They require specialised forest management practices during harvesting of native forest. Conversely, clayey soils formed on granite under wet eucalypt forest generally have low erodibility, medium to high levels of nutrients and high water-holding capacity. They have a low risk of erosion, high potential productivity and are suitable for conversion to plantations (Photo 2).

Although the soil-vegetation relationships outlined above apply on a broad scale, the distribution of soils at a detailed scale is more complex. This paper discusses granite-derived soils described to date in Tasmania but excludes soils found on King and Flinders Islands as well as those on the west coast and inland areas south of Waratah that were not examined due to their remoteness and / or lack of economic importance. This paper summarises the major properties of the soils and provides specific management guidelines for their sustainable use. It is intended to be a user-friendly guide to enable forest managers to

Photo 2. Good growth of an eight-year-old plantation of Eucalyptus globulus *on a gradational soil formed on granodiorite (Springfield soil-profile class).*

identify the various granitic soils and apply appropriate forest practices.

Environmental features

Parent materials

Four main types of parent material have been recognised:

1. *In-situ* granite / adamellite;
2. *In-situ* granodiorite;
3. Tertiary alluvial sediments derived from granite or granodiorite; and
4. Quaternary alluvial sediments derived from granite or granodiorite.

Soils on granite and adamellite have not been distinguished or separately described because, in many areas, these parent rocks are mapped as one unit, and it is difficult to find conclusive evidence of significant differences in soil properties. However, further detailed studies may indicate that soils formed on these two substrates could be separated. The *in-situ* granites and granodiorites are often deeply weathered, forming relatively sandy parent materials, particularly at lower elevations. Rock outcrops and / or large surface boulders are generally a characteristic feature of the granitic terrain. The distribution of surface rock is highly variable but appears to occur more frequently at higher elevations and on rolling to steep slopes. The granite-derived Tertiary and Quaternary sediments include sands, silts, clays and gravels but they occur much less extensively than *in-situ* granite.

Topography and climate

Granite outcrops from near sea level to over 1000 m in terrain dominated by hilly and mountainous land with only minor alluvial flats, depressions, fans and terraces. Undulating (3–10%) and rolling (10–30%) slopes are prevalent on low hills, with rolling and steep (> 30%) slopes dominant on the dissected hill country and mountains.

Climate varies from mild and subhumid (mean annual rainfall 600 mm) in coastal areas to cool and humid (mean annual rainfall > 1600 mm) in inland areas at higher elevations. A significant feature of rainfall in north-eastern Tasmania is the occurrence of high intensity, erosive rainfall events in coastal areas, particularly during summer. Lowlands near the coast generally have dry and warm summers with pronounced soil moisture deficits, whereas summer drought is much less severe and occurs less frequently in inland areas with higher rainfall.

Native vegetation

Native forest types are generally related to rainfall, with dry open eucalypt forest and woodland predominating in areas where mean annual rainfall is less than 1000 mm, and wet eucalypt forest, mixed forest and rainforest occurring in higher rainfall areas. However, there are exceptions. For example, near Upper Natone in north-western Tasmania where mean annual rainfall is between 1400–1500 mm, dry eucalypt forest occurs on hill slopes, with mixed forest (wet eucalypt / rainforest) in gullies. This association may be related to modification of the original wet forest by frequent fires.

Dry forest is dominated by *Eucalyptus amygdalina* and *E. obliqua* and less commonly *E. viminalis* over an understorey that often includes *Leptospermum scoparium, Epacris impressa, Pteridium esculentum, Acacia terminalis* and *Banksia marginata*. Drier sites have a more heathy vegetation with *Allocasuarina littoralis, Aotus ericoides, Baeckea ramosissima* and *Ricinocarpus pinifolius* in addition to those listed above. Sparse understorey and little ground cover are typical of dry *E. sieberi* forests along the east coast, particularly on the drier northerly slopes with high concentrations of gravel and sand in surface soils and subject to repeated burning.

Wet eucalypt forest is characterised by a canopy of *Eucalyptus regnans* and / or *E. obliqua* and occasionally *E. viminalis,* with an understorey dominated by *Pomaderris apetala, Dicksonia antarctica, Coprosma quadrifida, Olearia lirata,* and *Polystichum proliferum*. On sites with sandy soils of low fertility, the canopy is generally dominated by *E. obliqua* and *E. amygdalina* with an understorey of *Acacia dealbata, A. mucronata, Monotoca glauca* and *Zieria arborescens,* and a ground cover of *Pteridium esculentum*. *Eucalyptus delegatensis* is generally the dominant eucalypt at elevations exceeding about 400 m.

Rainforest or mixed forest predominates in the higher rainfall (> 1200 mm) areas. Common species include *Nothofagus cunninghamii, Atherosperma moschatum, Acacia dealbata,* and *Dicksonia antarctica* and *Eucalyptus regnans* with mixed forest communities. Scrub dominated by species of *Leptospermum* and *Melaleuca* or sedgeland-heathland dominated by *Gymnoschoenus sphaerocephalus* with scattered *Eucalyptus ovata* and / or *E. amygdalina* generally occurs in poorly drained depressions subject to seasonally high watertables.

Properties and distribution of forest soils on granite

Soil-profile classes

Early work on soils derived from granite in north-eastern Tasmania was carried out to investigate erosion problems (Davies and Neilsen 1987). Much of the forested granitic terrain was later mapped during a five-year program of soil characterisation and mapping initiated in northern Tasmania in 1990. Grant *et al.* (1995a, b), Hill *et al.* (1995), Laffan *et al.* (1995) and subsequently Laffan and McIntosh (2002) have defined and described 27 soil-profile classes and three soil variants.

The soil-profile classes have been differentiated on the basis of parent material, soil morphological features and native vegetation. Chemical, physical and mineralogical properties are considered to be relatively uniform within a soil-profile class. Variants are soil-profile classes of small areal extent that differ from the named class by some significant feature. Variants are defined to avoid the proliferation of soil-profile class names, particularly where it is difficult or impractical to map minor soil-profile classes. Each soil-profile class is identified by a local geographic name (e.g. Stronach soil-profile class is named after Mt Stronach near Scottsdale).

Profile features

Table 1 lists distinguishing soil-profile features, parent material and native vegetation for each soil-profile class and variant. The profile features include trends in soil texture with depth (texture-contrast, gradational, or uniform texture profiles), presence of bleached A2 layers, colour and texture of subsoils, and presence of hardpans. When used in conjunction with parent material and native vegetation types, the soil-profile features should enable forestry personnel to readily identify the various soil-profile classes formed on granite.

Soil-texture trends.—Texture-contrast, uniform and gradational texture profiles are all represented in soils derived from granite. Texture-contrast profiles have a sudden, marked increase in clay, usually between the topsoil and subsoil. Typically, the change from sandy surface layers to clayey subsoils occurs within a vertical distance of less than 10 cm. Conversely, uniform profiles have textures that do not change significantly with depth, whereas gradational profiles show a gradual increase in clay content with depth.

Bleached A2 layers.—Bleached layers are usually found in texture-contrast soils or uniform sands. Strongly bleached A2 layers are whitish or light grey when dry, whereas A2 layers with light yellow or light brown colours are designated as being weakly bleached. Where the lower 10–20 cm of the bleached layer is weakly cemented, it is described as having a hardpan. In the Trewalla soil-profile class, the hardpan is formed in the loamy layer underlying the bleached layer.

Subsoil structure.—Subsoil structure is a useful indicator of the effective rooting volume for trees, where soils with coarse structure provide less air and water than soils with fine structure. Subsoil structure (size, shape and degree of ped development) is related to native forest type. Under dry forest, peds tend to be coarse, particularly in soils with bleached layers where B horizons typically have coarse (50–100 mm or 20–50 mm) primary blocky or prismatic structure which breaks down into a finer (10–20 mm) secondary blocky structure. Black-coloured organic coatings frequently occur along major cracks and ped faces in the subsoils. Soils without bleached layers under dry forest generally have finer (< 20 mm) primary blocky structure in B horizons. Under wet forest, soils generally have 20–50 mm or 10–20 mm primary blocky structure which breaks down into 2–5 mm blocky or less than 2 mm granular structure.

Soil nutrients

Nitrogen and phosphorus are the most widespread limiting nutrients in Tasmanian forest soils, and soil N and P levels are used to indicate likely deficiencies in planted

Table 1. Key to soil-profile classes derived from granite according to parent material, native vegetation and profile features.

1. Soils on Quaternary sediments

(a) Under scrub and sedgeland-heathland

Hurst – Texture-contrast profiles with peaty topsoils overlying bleached coarse sands that in turn overlie grey clays.

(b) Under open dry eucalypt forest

Albion – Uniform coarse sandy profiles with many quartz gravels.

(c) Under wet eucalypt forest

Wombat – Gradational profiles with silty clay loams overlying yellowish brown clays.

2. Soils on Tertiary sediments

(a) Under heathy dry eucalypt forest

Duncraggen – Texture-contrast profiles with thick, strongly bleached coarse sandy A2 and many quartz gravels overlying humic/iron pans and clays.

(b) Under dry eucalypt forest

Lauderdale – Gradational profiles with loamy topsoils overlying yellowish red clay loams and clays.

Tonganah – Texture-contrast profiles with strongly bleached coarse sandy A2 overlying clay loams.

Tebrakunna – Uniform profiles with strongly bleached coarse sandy A2 overlying thick, cemented pans.

(c) Under wet eucalypt forest

Cascade – Uniform coarse sandy profiles with strongly bleached A2 overlying thick, cemented pans.

3. Soils on granite (and adamellite)

(a) Under dry eucalypt forest

Jensen – Texture-contrast profiles with strongly bleached coarse sandy A2 forming a hardpan overlying yellowish brown clays.

Jensen variant – Similar to Jensen but do not have a hardpan in the A2 layer.

Wurrawa – Gradational profiles with loams overlying yellowish brown and brown clays.

Rossarden – Gradational profiles with weakly bleached loamy coarse sand A2 overlying yellowish brown coarse sandy loams.

(b) Under wet eucalypt forest

Crystal – Gradational profiles with dark grey loamy coarse sands overlying black gravelly coarse sandy loams.

Trewalla – Texture-contrast profiles with weakly bleached A2 overlying brown clay loam hardpans.

Panic – Uniform profiles with thin humic silt loam topsoils overlying brown clay loams and loams.

Hogarth – Gradational profiles with sandy loams overlying red clay loams.

Stronach – Gradational profiles with coarse sandy loams or coarse sandy clay loams overlying yellowish brown clays.

Table 1. Continued.

Paris/Dolcoath[1] – Texture-contrast profiles with strongly bleached coarse sandy A2 overlying yellowish brown sandy clays.

Paris pan variant – Similar to Paris but have a hardpan in the lower A2.

Cuckoo – Gradational profiles with coarse sandy loams overlying yellowish brown to brown coarse sandy clays. All layers have weak strength.

(c) Under open wet eucalypt forest/damp eucalypt forest and mixed forest

Memory – Gradational profiles with coarse sandy loams overlying brown coarse sandy clay loams with abundant gravels.

(d) Under rainforest and scrub

Jessop – Gradational profiles with humic loams overlying coarse sandy clay loams and thin humic and iron pans.

Jessop variant – Uniform profiles with peaty loams overlying dark yellowish brown loams with very weak strength.

4. Soils on granodiorite

(a) Under dry eucalypt forest

McKay – Texture-contrast profiles with strongly bleached coarse sandy A2 overlying yellowish brown coarse sandy clay.

Fraser – Gradational profiles with weakly bleached coarse sandy loam A2 overlying brownish yellow silty clay loams. Many red mottles occur below 50 cm.

(b) Under wet eucalypt forest

Arnon – Texture-contrast profiles with strongly bleached coarse sandy A2 overlying brown clays.

Blumont – Gradational profiles with sandy clay loams overlying brown coarse sandy clays. Red mottles occur below 50 cm.

Springfield – Gradational profiles with clay loams overlying red clays.

Diddleum – Gradational profiles with loams overlying yellowish brown and brown clay loams with weak strength.

[1] Paris and Dolcoath soil-profile classes have very similar profile features.

trees. Soil organic matter content based on organic carbon (C) levels has also been used as a guide to soil N content and overall soil nutrient status. However, because of widely varying C / N ratios and contamination of organic C by charcoal, organic C levels are not always a good indication of soil nutrient status.

Organic C, total N and total P for the topsoil layer (0–30 cm) are shown in Table 2. The 0–30 cm layer is considered to give a more representative indication of soil nutrient levels for trees compared to the relatively nutrient-rich 0–10 cm layer.

Results of laboratory analyses for individual soil layers are published elsewhere (Grant *et al.* 1995a, b; Hill *et al.* 1995; Laffan *et al.* 1995; Laffan and McIntosh 2002).

The results show some trends related to vegetation type and the presence or absence of bleached A2 layers. Generally, soils under wet forest have medium to high levels of nutrients compared to soils under dry forest, which invariably have low levels of total N (< 0.1%) and total P (< 100 mg / kg). The exceptions are soils with bleached A2 layers occurring under wet forest, which have low levels of nutrients.

Table 2. Organic/total C, total N and total P in the 0–30 cm layer for a range of soils.

Soil-profile class	Organic C (%)	Total N (%)	Total P (mg/kg)
1. Soils on Quaternary sediments			
(a) Under scrub and sedgeland-heathland			
Hurst	10.8[1]	0.01	66
2. Soils on Tertiary sediments			
(a) Under dry forest			
Duncraggen	2.0[1]	0.08 (L)[3]	32 (L)[3]
Lauderdale	1.1[1]	0.06 (L)	142 (M)
Tonganah	1.0[1]	0.04 (L)	62 (L)
(b) Under wet forest			
Cascade	2.0[2]	0.08 (L)	35 (L)
3. Soils on granite			
(a) Under dry forest			
Jensen	0.8[1]	0.03 (L)	44 (L)
Jensen variant	0.8[1]	0.03 (L)	77 (L)
Wurrawa	1.3[1]	0.05 (L)	93 (L)
(b) Under wet forest			
Trewalla	3.6	0.2 (M)	96 (L)
Stronach	2.2[1]	0.2 (M)	276 (H)
Panic	4.9[2]	0.2 (M)	120 (M)
Paris	3.9[1]	0.2 (M)	60 (L)
Cuckoo	4.7[1]	0.3 (H)	440 (H)
4. Soils on granodiorite			
(a) Under dry forest			
McKay	1.1[2]	0.04 (L)	na
Fraser	1.0[2]	0.04 (L)	32 (L)
(b) Under wet forest			
Blumont	1.8[2]	0.14 (M)	na

na = not analysed 0–30 cm.
[1] C determined by Walkley-Black method.
[2] C determined by ignition method.
[3] Ratings for total N and P (L = low, M = medium, H = high).

Distribution

Soils under scrub and sedgeland-heathland occur in small depressions and valley flats, mainly in north-eastern Tasmania, where coarse sandy sediments have accumulated and are subject to prolonged waterlogging.

Soils under dry forest occur widely throughout northern Tasmania where mean annual rainfall is below about 1000 mm. They also occur in areas with higher rainfall, particularly on dry, north-facing slopes that are susceptible to frequent fires. Soils with uniform, coarse sandy and fine gravelly profiles (Albion soil-profile class) occur on lower hill slopes and in drainage depressions in north-eastern and eastern Tasmania. They appear to be confined to the coastal and adjacent hilly areas that are highly susceptible to periodic high intensity rainfalls.

Duncraggen, Tonganah, Lauderdale and Tebrakunna soil-profile classes occur on undulating and rolling low hills formed in Tertiary sediments distributed throughout the north-east. Duncraggen and Tonganah soils cover much larger areas than Lauderdale and Tebrakunna soil-profile classes.

The texture-contrast Jensen soil-profile class occurs widely across northern and eastern Tasmania on undulating and rolling hills at elevations below about 300 m, and usually occurs as the major soil in association with smaller areas of the gradational Wurrawa soil-profile class. McKay and Fraser soils occur on lowlands below about 300 m elevation, with McKay soil-profile class being located mainly in Goulds Country (with a smaller area near Nabowla) and Fraser soil-profile class occurring in small areas in association with the dominant McKay soil-profile class. Rossarden soil-profile class has been recognised on rolling and steep slopes on the southern side of Ben Lomond at elevations greater than 600 m, but may occur elsewhere under dry forest in the north-east.

Soils under wet forest generally occur in areas where mean annual rainfall exceeds about 1000 mm, mostly above 300 m elevation, although they are also found on slopes with shady aspects or in gullies and along drainage depressions and streams in areas with lower rainfall and at lower elevation. Wombat and Cascade soil-profile classes formed on Quaternary and Tertiary sediments respectively have rather limited distribution compared to soils formed on *in-situ* granitic rocks. The Stronach, Cuckoo, Blumont, Springfield and Diddleum soil-profile classes occur widely on undulating, rolling and steep slopes throughout the north-east, whereas Hogarth soil-profile class has a very limited distribution mainly around the Johnstones Hill / Cuckoo Hill area south-east of Scottsdale.

The Paris soil-profile class and Paris variant generally occur as subdominant components in association with Stronach or Cuckoo soil-profile classes, although Paris soils are dominant in areas south-east of Derby, south of Upper Natone and near Cascade dam. Panic soil-profile class occurs widely south of Upper Natone but probably also occurs elsewhere as a minor component in association with Stronach soil-profile class. Arnon soils occupy small areas west of Kamona Ridge and Dolcoath soils occur south of Cethana dam.

Trewalla soils generally occupy small areas in association with Stronach soils, but they occur more frequently near South Springfield. Crystal soil-profile class dominates a relatively small area adjacent to Lottah Road near Crystal Creek, but minor occurrences are also found elsewhere in association with Stronach soils. Memory soil-profile class occupies higher elevation (> 500 m) sites, mainly in the vicinity of Ben Ridge Road and Roses Tier. Jessop soils are confined to elevations exceeding about 700 m on the Rattler Range.

Management requirements

The soil degradation potential, site productivity and recommended management practices for native forest logging and development of plantations have been specified for each soil-profile class and variant (Grant *et al.* 1995a,b; Hill *et al.* 1995; Laffan *et al.* 1995; Laffan and McIntosh 2002). In this section, selected information on the management requirements of individual soils is presented as a summary. In Table 3, the soils have been rated for erodibility, nutrient status and site productivity for plantations, and the main factors limiting site productivity have been listed. Table 4 outlines recommended treatments for site cultivation and fertilisation during plantation development. In both tables, the soils have been grouped according to three main vegetation types (scrub and sedgeland-heathland, dry forest,

Table 3. Soil-profile classes in relation to erodibility, nutrient status and site productivity (prod.) for plantations.

Native vegetation / soil features	Soil-profile class	Erodibility	Nutrient status	Site prod.	Main limiting factors
Soils under scrub and sedgeland-heathland					
	Hurst	Mod–high	Low	Very low	Very poor drainage
Soils under dry forest					
• Uniform, coarse sandy and fine gravelly profiles	Albion	Very high	Low	Very low	Very low water availability, nutrients
• Strongly bleached layer overlying iron / humus pans	Duncraggen	High	Low	Very low	Very low water availability, nutrients
• Strongly bleached layer (and occasional hardpan) overlying clays	Tonganah Jensen Jensen var. McKay	High	Low	Low	Nutrients, restricted rooting depth
• Strongly bleached layer and thick hardpan	Tebrakunna	High	Low	Very low	Nutrients, restricted rooting depth, poor drainage
• Weakly bleached layer	Rossarden	Moderate	Low	Low	Nutrients, restricted rooting depth
	Fraser				Nutrients
• Without bleached layer	Lauderdale Wurrawa	Moderate	Low	Low	Nutrients
Soils under wet forest					
• Strongly bleached layer and occasional hardpan	Paris Paris var. Dolcoath Arnon	Mod–high to high	Low	Low	Nutrients, restricted rooting depth
• Strongly bleached layer and thick hardpan	Cascade	Mod–high	Low	Very low	Restricted rooting depth, poor drainage, nutrients
• Weakly bleached layer and hardpan	Trewalla	Moderate	Low	Low	Restricted rooting depth, nutrients
• Without bleached layer	Wombat	Low	Medium–high	High	Medium levels of nutrients in some soils
	Hogarth	Low	High	High[3]	Negligible
	Panic	Moderate	Medium	High[3]	Medium nutrient levels
	Stronach	Low–moderate[1]	Medium–high	High[3]	Medium nutrient levels in some soils
	Blumont	Low	Medium–high	High[3]	Medium nutrient levels in some soils

Table 3. Continued.

Native vegetation / soil features	Soil-profile class	Erodibility	Nutrient status	Site prod.	Main limiting factors
	Springfield	Low	High	High[3]	Negligible
	Crystal	Moderate	High	High[3]	Negligible
	Memory	Moderate	Medium[2]	High[3, 4]	Medium levels of nutrients, frost / exposure locally
	Cuckoo	Moderate	High	High[3, 4]	Frost / exposure locally
	Diddleum	Moderate	High	High[3, 4]	Frost / exposure locally
	Jessop	Moderate	High	Medium–high[3, 4]	Restricted rooting depth, frost / exposure locally
	Jessop var.	Moderate	High	High[3, 4]	Frost / exposure locally

[1] Moderate in soils with coarse sandy loam topsoils.

[2] Low to medium in soils with thin (< 10 cm) A1 horizon under damp forest.

[3] High rating for deep (> 80 cm) soils only. Shallower and stony soils have medium or low productivity.

[4] High rating only for deep soils at elevations less than 850 m in north-eastern Tasmania, and less than 600 m elsewhere. Plantations established on exposed ridges are also susceptible to windthrow.

wet forest) and then subdivided on easily recognisable profile features such as presence of bleached layers, degree of bleaching, and hardpans. This has enabled the soil-profile classes to be allocated into groups requiring similar management treatments.

Soils with very low site productivity (Hurst, Albion, Duncraggen, Tebrakunna and Cascade soil-profile classes) are not suitable for development to plantations, and following logging they should be regenerated to native forest. However, many of these sites are of such low productivity that their suitability for sustained production forestry is doubtful. Some of the soils are apedal, with upper soil layers dominated by loose gravel and sand particles with very low levels of organic matter, and are often devoid of any humus development. Localised patches of litter accumulation do occur but these generally produce only shallow, humus-enriched surface horizons that are often less than 2 cm thick, with few soil fauna. Apart from Hurst and Cascade soil-profile classes, the soils have high or very high erodibility and require particular care during harvesting operations to avoid initiating erosion. Because of low levels of nutrients, they are also very susceptible to nutrient depletion and require minimal disturbance to surface soil layers when logged. In dry areas, rapid soil creep and accumulation of unconsolidated gravel frequently occur on steep slopes.

Soils with low site productivity (Tonganah, Jensen, Jensen variant, McKay, Lauderdale, Rossarden, Wurrawa, Fraser, Paris, Paris variant, Dolcoath, Arnon, Trewalla soil-profile classes) are only marginally suitable for plantations because of low levels of nutrients, and also restricted rooting depth / volume related to hardpans in some of them (Jensen, Trewalla, Paris variant). In all of these soil-profile classes, coarse blocky and prismatic structures in the clayey subsoils may also restrict rooting volume. They all require deep ripping and mounding to try and ameliorate limitations to rooting depth / volume, as well as primary and secondary fertilisation to overcome the low levels of soil nutrients. Where spot cultivation is used as an alternative to deep ripping and mounding, it needs to penetrate below any hardpans in order to avoid the ‘bathtub effect’ where water ponds on top of the hardpans (Photo 3). However, until reliable information on growth rates and the economics of site cultivation and secondary

Table 4. Soil-profile classes in relation to recommended treatments for plantation development.

Native vegetation / soil features	Soil-profile class	Site cultivation	Fertilisation
Soils under scrub and sedgeland-heathland			
	Hurst	na[1]	na
Soils under dry forest			
• Uniform coarse sandy and fine gravelly profiles	Albion	na	na
• Strongly bleached layer overlying iron / humic pans	Duncraggen	na	na
• Strongly bleached layer (and occasional hardpan) overlying clays	Tonganah Jensen Jensen var. McKay	(Deep rip and mound or spot cultivate)[2]	(Primary and secondary)
• Strongly bleached layer and thick hardpan	Tebrakunna	na	na
• Weakly bleached layer	Rossarden Fraser	Deep rip and mound or spot cultivate	Primary and secondary
• Without bleached layer	Lauderdale Wurrawa	Deep rip and mound or spot cultivate	Primary and secondary
Soils under wet forest			
• Strongly bleached layer and occasional thin hardpan	Paris Paris var. Dolcoath Arnon	(Deep rip and mound or spot cultivate)[2]	(Primary and secondary)
• Strongly bleached layer and thick hardpan	Cascade	na	na
• Weakly bleached layer and hardpan	Trewalla	(Deep rip and mound or spot cultivate)[2]	(Primary and secondary)
• Without bleached layer	Wombat	Deep rip and mound or spot cultivate	Primary and secondary[4]
	Hogarth	(As above)	(As above)
	Stronach	(As above)	(As above)
	Panic	(As above)	(As above)
	Blumont	(As above)	(As above)
	Springfield	(As above)	(As above)
	Crystal	(As above)	Primary
	Memory	Mounding only[3, 5]	Primary and secondary
	Cuckoo	Mounding only[3, 5]	Primary
	Diddleum	Mounding only[3, 5]	Primary
	Jessop / Jessop var.	Mounding only[3, 5]	Primary

fertilisation have been established, these soils are best avoided for conversion to plantations. The soil-profile classes with best potential for plantations are those without bleached layers under wet forests (Wombat, Hogarth, Panic, Stronach, Blumont, Springfield, Crystal, Memory, Cuckoo, Diddleum, Jessop, Jessop variant). They have medium to high levels of nutrients and no major limitations affecting rooting depth / volume except for restricted rooting conditions occurring in shallow and stony soils. Shallow and stony soils generally occupy relatively small areas in association with rock outcrops. They have lower productivity and are more susceptible to windthrow, particularly where located on exposed ridges, compared to adjacent deep soils. Plantations established on exposed ridges will require specialised management to minimise the risk of windthrow. The better soils have deep A1 horizons and textures are generally similar across the range of parent materials. However, the nutrient status of these soils varies widely due in part to variations in minerals in the parent rock. Soils with medium levels of nutrients generally have organic-rich topsoil layers less than 20 cm thick, and they will probably require some secondary fertilisation to achieve high rates of growth.

Soils at elevations exceeding about 400 m are generally easily penetrable by tree

Photo 3. Cultivation that does not take account of soil limitations can lead to poor production and, in extreme cases, death of young trees. In this example, spot cultivation has occurred in an area with Cascade soils. These soils have thick subsoil pans, cemented by humic substances and iron compounds. The spot cultivator has been unable to penetrate the pan. Rain following cultivation has saturated the soil, leading to waterlogged soil layers above the pan. These saturated soil layers become anaerobic, causing death of roots of growing seedlings planted on mounds.

Footnotes to Table 4.

[1] Not applicable. These soils are not suitable for development to plantations.

[2] These soils are only marginally suitable for plantations due to low levels of nutrients and, in some cases, restricted rooting depth due to hardpans and poor soil structure. Until reliable data on growth rates are available, these soils are best avoided for conversion to plantations.

[3] Soils at elevations above about 400 m generally have weak / very weak strength and require mounding only. Sites with good drainage of cold air and not susceptible to severe frosting can be planted without mechanical cultivation. Plantations established on exposed ridges require specialised management to minimise risk of windthrow.

[4] Soils with thick (> 20 cm) dark topsoils generally have high levels of nutrients and do not require secondary fertilisation.

[5] Alternatively spot cultivate.

roots due to weak or very weak soil strength and / or fine structure throughout the profile. Such soils do not require deep ripping or spot cultivation to encourage root development, but mounding is recommended to elevate planted seedlings above the layer of coldest air in winter / spring, to mineralise nutrients, and to aid weed control, thus improving survival and initial growth rates of the plantations. However, sites with good drainage of cold air and not susceptible to severe frosting may be planted without any cultivation apart from manual pitting, following clearing and windrowing. In north-eastern Tasmania, the upper limit of sites with high productivity is about 850 m but is lower where sites are exposed to strong winds or are susceptible to accumulation of cold air and severe frosting. Further westwards, the altitudinal limit for high site productivity decreases to about 600 m.

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