A rapid field method for assessing site suitability for plantations in Tasmania's State forest

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Abstract

A rapid field method has been developed for recording essential land attributes and interpreting the data for site productivity and suitability for plantations in Tasmania. The method can be used in native forests or on cleared land and requires only minimal equipment: soil auger, compass, hip chain, and field sheets for encoding and interpreting the data. Observations of soil and site attributes are made, preferably at least every 100 m, along transects spaced 200 m apart, giving a sampling intensity of about one observation every two hectares. The sampling intensity can be adjusted to suit the soil and topographic variability encountered. At each sample site, the time required to auger the soil, record the data and determine site productivity and suitability is generally about five to ten minutes.

Four classes of site productivity are defined in terms of peak mean annual volume increment (MAI expressed as m^3/ha/yr), ranging from Productivity Class 1 (high productivity, MAI > 20) to Productivity Class 4 (very low productivity, MAI < 10). Productivity class is assessed by carrying out five simple steps in which various soil and site features are recorded and interpreted using a series of tables. Site suitability takes account of management constraints and land degradation hazards as well as site productivity. These are assessed in a further five steps to arrive at a final rating of site suitability (suitable, marginally suitable, unsuitable) for plantations.

Because any limiting soil and/or other site factors are specified, management practices to ameliorate site limitations can also be prescribed where appropriate. The method is being used by Forestry Tasmania as a tool for selecting sites suitable for plantation development.

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Introduction

Plantations of both softwoods and hardwoods are being established at an increasing rate on private and Crown Lands in Tasmania. This trend is expected to continue well past the year 2000. The importance of site productivity (or site quality) on the profitability of commercial plantations has been emphasised by several studies in Tasmania (Neilsen 1990; Gerrand *et al.* 1993; Candy and Gerrand 1997). Site quality is a measure of the relative productive capacity of a site for specified forest species and is determined by soil and climatic attributes. Site suitability is a broader concept tied to the sustainability of plantations. It takes into account forest management aspects and land degradation hazards as well as site quality. In addition to allowing selection of the most appropriate sites for plantations, soil resource information can be used in conjunction with the *Forest Practices Code* (Forestry Commission 1993) to prescribe appropriate land management practices for the establishment, tending and harvesting of plantations.

Tasmania has a highly diverse and complex pattern of soils resulting from the wide range of landforms, geology, climate and vegetation. A soil-mapping project to provide detailed information on the spatial distribution and properties of soils in

Tasmania's State forest commenced in 1990 (Laffan and Neilsen 1997). By the end of the five-year project, three 1:100 000 topographic sheets covering 154 000 ha had been mapped at a scale of 1:50 000 in the north (Laffan *et al.* 1995; Grant *et al.* 1995a; Hill *et al.* 1995), together with reconnaissance soil surveys of a further 6500 ha elsewhere in the State. A primary objective of the soil mapping was to determine site suitability for plantations. A handbook characterising a wide range of representative forest soils from around Tasmania, together with assessments of plantation potential, was also completed as part of the project (Grant *et al.* 1995b). This information forms a solid framework for further soil characterisation.

Because of the increasing demand for soil data in areas not covered by the mapping project and only limited scientific expertise available for additional field work, it was decided to investigate a field method for assessing plantation potential that could be used anywhere in the State by non-specialist staff. The essential requirements were that the method had to be relatively simple and suitable for rapid use in forested terrain, with only minimal equipment. The ability to carry out all assessments of site suitability in the field under any weather conditions was also seen as an advantage. Although a computer program (Private Forests Tasmania 1999) is available for assessing site productivity for *Eucalyptus globulus* based on PROMOD (Battaglia and Sands 1997), it does not specify how users should collect or interpret the required soil data. Also, there is no facility for assessing management and land degradation limitations or for determining site suitability. For these reasons, a user-friendly field method was developed that allows the determination of both site productivity and suitability for plantations. The new method shows step by step how to record basic soil information and, together with data on rainfall, topography, geology and vegetation, how to assess and classify plantation suitability for hardwoods (*Eucalyptus globulus, E. nitens*) and softwood (*Pinus radiata*). It was developed from an earlier, less detailed field system used to assess plantation potential in north-western Tasmania (Laffan *et al.* 1998). The method is designed primarily for use in Tasmania's State forest, but can be modified where appropriate for use on private land.

Ratings of site productivity and suitability for plantations

As part of the five-year soil mapping project, a systematic and objective methodology for assessing site productivity for both hardwood (*E. globulus, E. nitens)* and softwood (*Pinus radiata*) plantations was developed for Tasmania (Laffan 1994). The methodology is based on the assessment of the land attributes associated with tree growth. It is assumed that the land attribute which most severely limits plantation growth and which cannot be readily ameliorated will determine the overall rating of site productivity. A test of the system (Osler *et al.* 1996) on a limited range of sites in northern Tasmania indicated that its predictive ability could be significantly improved simply by raising the altitude limit for *E. globulus.* Minor changes to limits for altitude and rainfall, and measures of nutrient status were incorporated into a revised methodology (Laffan 1997). Comparison of the revised version with several other growth models, including PROMOD (Battaglia and Sands 1997) and PLANTGRO (Hackett 1991) and using the data for northern Tasmania, shows that they all give broadly similar results (P. Sands, pers. comm.).

To classify potential site productivity, four productivity classes are defined in terms of peak mean annual volume increment (MAI) expressed as m^3/ha/yr:

Productivity Class 1 = high productivity (MAI > 20);
Productivity Class 2 = medium productivity (MAI 15–20);
Productivity Class 3 = low productivity (MAI 10–15); and
Productivity Class 4 = very low productivity (MAI < 10).

The classification aims to give a ranking of site quality from the best (Productivity Class 1) to the poorest (Productivity Class 4) and to indicate approximate rates of growth. Because the MAI ratings are based solely on data from hardwood plantations, they are most applicable to eucalypts and are less precise for radiata pine (*Pinus radiata*). When new information from growth plots in both hardwood and softwood plantations becomes available, the classification will be revised where appropriate.

A system for classifying site suitability for plantations was developed in conjunction with the classification of site productivity (Laffan 1994, 1997). Four classes of suitability were defined: Suitability Class 1 = highly suitable; Suitability Class 2 = moderately suitable; Suitability Class 3 = marginally suitable; and Suitability Class 4 = unsuitable. Suitability Class 1 is considered to have no significant limitations for productivity or sustainable use for plantation forestry, whereas Suitability Classes 2 to 4 have increasingly severe limitations or hazards affecting productivity and/or management and/or land degradation. To simplify the assessment and classification procedures, a suitability system with three classes only was developed:

1 = suitable;
2 = marginally suitable; and
3 = unsuitable.

This was achieved by combining the highly suitable and moderately suitable classes from the original classification.

Factors affecting site suitability for plantations

The various soil and site factors affecting the potential of land for sustainable plantation use have been outlined by Laffan (1997). Site productivity is dependent on inherent soil and climatic attributes, including temperature regime, moisture availability, drainage characteristics, tree-rooting conditions and nutrient availability. These attributes can be measured or assessed using a variety of methods, including laboratory analysis of soil properties, measurement of climatic parameters and field interpretations of basic soil and topographic features. Field observations of appropriate soil and landform features, together with data on geology, rainfall and elevation, enable relatively rapid assessments to be made of site productivity. For example, elevation and landform can be used as surrogates for temperature regime. Moisture availability can be assessed from mean annual rainfall and soil properties affecting soil moisture storage such as depth, texture and stoniness. Drainage characteristics are most easily assessed from soil colour and vegetation. Rooting conditions include effective root depth and ease of root penetration. Effective root depth is assessed by measuring the depth to a layer that physically impedes root development such as bedrock, cemented or compacted pans and slowly permeable clays. Ease of root penetration can be estimated from the content of soil rock (floaters) occurring within the effective root depth and also from the type, size and degree of soil structural development. Nutrient availability is best assessed from laboratory analysis to determine levels of nitrogen (N) and phosphorus (P) but can be estimated by reference to geology, soil features, vegetation and land use.

The assessment of site suitability requires further information on management constraints (fertiliser requirement, trafficability, soil workability) as well as land degradation hazards (flood risk, erosion risk and landslide risk). Fertiliser requirement is assessed from nutrient availability and soil texture and thickness. Trafficability and soil workability are determined from slope angle and surface rock cover. Erosion risk is assessed from soil erodibility, slope and rainfall intensity whereas flood and landslide risks are based on landform features.

Equipment and sampling intensity

Equipment and materials required

Equipment required in the field is minimal: soil auger, compass, hip-chain, small water container, and data sheets for encoding and interpreting the data. A field sheet (Appendix 1) was designed specifically for recording soil and site attributes affecting site productivity and suitability for plantations. A series of tables is then used to interpret the data and assess plantation potential. Other information needed but which can be accessed in the office include geological maps (preferably at 1:50 000 scale or larger if available), long-term records of mean annual rainfall or isohyet maps, and topographical maps (at 1:25 000 scale or larger if available).

Sampling intensity

Because of the highly diverse pattern of soils occurring over much of Tasmania and the need to acquire detailed information at the forest compartment level, a systematic grid sampling method using transects is recommended. The sampling intensity depends on soil variability and on whether the survey is detailed or reconnaissance. Reconnaissance surveys are normally only carried out to stratify large areas into compartments requiring more detailed inspections. For reconnaissance purposes or where the geology and soil pattern are relatively uniform, transects are spaced 200 m apart and observations of soil and site attributes are recorded every 200 m (sampling intensity one observation every four hectares). Transect spacing may be increased to 400 m or 600 m for large areas of uniform soils. Intermediate 'fill-in' transects can be made later to locate boundaries of any recorded soil changes. Where the geology and soils are moderately variable, the recommended sampling intensity is one observation every two hectares made at 100 m intervals along transects spaced 200 m apart. This is regarded as the standard sampling intensity to be used for most compartment surveys. Where the soils or terrain are highly variable, for example, areas with a widely varying cover of surface rock, then a sampling intensity of one observation every hectare is recommended.

Observations of soil and land surface features must be made from undisturbed sites, taking care to avoid snig tracks and other areas disturbed by machinery, erosion, tree uprooting or landslip.

Procedures for assessing site productivity and suitability

Assessing site productivity for plantations

STEP 1. Record mean annual rainfall and elevation range

Use long-term rainfall data from nearby stations or from isohyet maps to record mean annual rainfall to the nearest 50 mm (if below 1000 mm) or to the nearest 100 mm (if above 1000 mm). Mean annual rainfall may have to be adjusted downwards to account for very stony, shallow or coarse sandy soils with poor water-holding capacity, or upwards, if soils occur on protected, shady-aspect slopes or gullies, or have significant subsurface water inputs.

Record elevation range from 1:25 000 scale topographic maps (or 1:10 000 maps if available).

STEP 2. Record native vegetation type and species, and rock type (geology)

Record native vegetation type and the ground, shrub and canopy species within a radius of about 20 m from the observation site. Use the codes given in Appendix 2. Where mean annual rainfall is in the 600–1000 mm zone, wet and damp eucalypt forest types are used to modify site productivity class (see Table 3).

Record rock type(s) using the codes in Appendix 2. Determine likely rock type(s) from geological maps prior to carrying out field work and confirm during site inspection. If in doubt, then collect specimens for identification by a specialist.

STEP 3. Identify and record soil profile features (colour, texture, and depth of each soil layer to a minimum depth of 80 cm or to an impeding layer, if shallower)

Use an auger to bore into the soil at right angles to the soil surface. Record the depths (to the nearest 1 cm for organic surface layers and to the nearest 5 cm for mineral layers) at which major changes in colour and / or texture become apparent. Use the codes given in Appendix 2 for recording colour and texture of a moist sample of soil. If the sample is dry, then moisten using water. To determine colour, break open a soil clod and record the colour(s) in a freshly exposed face. Visually estimate approximate percentage occurrence. Colours which cover between 2% and 50% of an exposed face (mottles) should be recorded inside brackets. For example, (G, R) indicates that grey- and rusty-coloured mottles occupy 2–50% of an exposed soil face. Do not record mottle colours covering less than 2%.

Texture should be determined using a moist sample of soil of sufficient size to fit comfortably into the palm of the hand. The aim is to classify soil texture into one of the following four broad classes:

1. **Sandy.** Moist soils feel very gritty and have nil or only weak coherence when squeezed.
2. **Loamy.** Moist soils are coherent when squeezed. It is preferable to subdivide loamy soils into sandy loams (soils feel very sandy), silt loams (soils have a smooth or 'silky' feel), and clay loams (soils are moderately plastic and form a ribbon of 40–50 mm when pressed out between thumb and forefinger).
3. **Clayey.** Moist soils are strongly plastic and will form ribbons greater than 50 mm when pressed out between thumb and forefinger. Note that sandy, loamy and clayey soils can also have an appreciable content of organic matter, particularly in poorly and very poorly drained sites. In such soils, use a humic texture modifier; for example, humic loam (HL).
4. **Peaty.** Soils are dominated by organic materials that have accumulated under conditions of excessive wetness.

Where auger penetration is stopped by rock then record depth and try to determine whether the rock is bedrock (fixed rock) or a floater (soil rock: gravel, cobble, stone or boulder). Distinguishing between bedrock and floaters is difficult when augering in rocky soils. In most cases, floaters will be impeding auger penetration rather than bedrock. If bedrock is exposed at sites within a radius of 10 m or is visible in nearby road batters, then assume that it is restricting auger penetration at the observation site and write 'bedrock' (or BR) on the field sheet. Otherwise, assume that the rocks are floaters and write 'floaters' (or FL), and proceed as outlined in the section *Ease of root penetration*. If hardpans (compact or cemented layers difficult to auger even when moist) occur, record depth and use the code in Appendix 2**.**

STEP 4. Determine soil properties associated with site productivity (effective root depth, ease of root penetration, drainage class, nutrient availability)

- *Effective root depth (ERD)*

If a limiting layer (see Table 1) occurs within 80 cm, then record depth to nearest 5 cm. If no limiting layer occurs within 80 cm, then record effective root depth as greater than 80 cm. For soils dominated by cracking clays which, when dry, form open cracks at least 5 mm wide, record effective root depth as less than 45 cm. Massive or coarsely structured and slowly permeable clays generally occur as the subsoils of texture-contrast soils under dry forest. They are usually characterised by dark brown or black coatings of organic matter down cracks. Reference may need to be made to soil pits to determine whether clayey subsoils limit root depth. Record effective root depth as the depth to the clay layer. The distribution and length of roots exposed on uprooted trees generally provide a good indicator of effective root depth.

Because augering is not a reliable method for assessing stoniness, very stony layers (> 90% stones) will need to be determined from a vertical exposure through the soil profile. (See the section *Ease of root*

Table 1. Soil materials that may form a limiting layer to root penetration.

1. Very abundant (> 90%) coarse (> 2 mm) fragments (gravels, stones, boulders) with negligible fine earth (< 2 mm).
2. Massive or coarsely structured (> 20 mm) and slowly permeable clay (generally characterised by dark brown or black coatings of organic matter down major cracks).
3. Cracking clays which, when dry, form open cracks at least 5 mm wide extending from the subsoil to, or just below, the soil surface.
4. Hard, cemented or compacted pans.
5. Waterlogged layer which is seasonally (> 2–3 months) or permanently saturated. This attribute is accounted for in drainage class (Table 2).
6. Bedrock (includes hard or very hard, unweathered rock and relatively soft, but dense and coherent, strongly weathered rock).

penetration.) At sites where floaters (soil rock) occur, do not record depth (insert a '–' or write NA in ERD box) and proceed to the section *Ease of root penetration*.

- *Ease of root penetration (soil rock)*

Soil rock (floaters) refers to gravels (0.2–6 cm), cobbles (6–20 cm), stones (20–60 cm) and boulders (> 60 cm) below the soil surface. Soil-rock content is estimated for the whole soil profile to a depth of 80 cm or within the effective root depth, if shallower. Estimate visually from a vertical exposure; that is, dig a hole or use a road batter or ditch. Estimate average stoniness to the nearest 10% and record as one of the per cent classes given in Appendix 2. Note that any layer with more than 90% stones defines the effective root depth. Soil-rock content cannot be reliably assessed from auger observations. Penetration by an auger can be severely impeded in sites with a low rock content as well as in sites with a very high rock content. At sites where auger penetration is impeded by soil rock, then extra borings are made as follows: (1) where the first auger boring does not exceed a depth of 25 cm, then carry out a further five auger borings within a radius of 5 m; (2) where the first auger boring is between 25–45 cm, then carry out two extra auger borings. In both cases, record the colour and texture of the deepest auger boring. Where the depth of the first auger boring is between 45–80 cm, then record soil features for this observation. If road cuttings do not occur nearby and digging pits is not warranted, then use the following approximations for the deepest auger boring (do not record depth in ERD box); that is, record soil rock as greater than 50% when depth is less than 25 cm, as 30–50% when depth is between 25 and 45 cm, and as less than 30% when depth is between 45 and 80 cm.

Ease of root penetration may also be affected by poor soil structure, but this limitation is ignored because structure cannot be determined from auger observations.

- *Drainage class*

Drainage class is determined on the basis of subsoil colour and vegetation (Table 2). Estimate whether grey (light or medium grey) mottles in subsoils occur within the range 2–50%, or whether grey colours are dominant (> 50%). Ignore dark grey mottles or light and medium grey mottles that are indistinct and only evident on close inspection of the soil. If grey mottles occupy about 50% of exposed faces in all or most subsoil layers, then record drainage class as imperfect, rather than poor. Use the codes listed in Appendix 2. Some soils with impeded drainage on basalt or dolerite have numerous gravel-sized nodules/concretions

Table 2. Drainage classes in relation to soil colour, texture and vegetation.

Drainage class	Soil colour, texture, vegetation
Rapidly drained	Uniform colours below topsoil. Usually deep sands or very stony or very shallow soils.
Well drained	Uniform yellow, brown or red colours below topsoil. Rusty-coloured mottles may occur at depths below 60 cm. Textures are usually loams or clays.
Moderately well drained	Grey mottles (2–50% of cut faces) occur between topsoil and 30 cm and overlie yellow, brown or red colours, or they occur at depths below 60 cm, or grey colours are dominant (> 50% of cut faces) below 80 cm. Textures are usually loams or clays.
Imperfectly drained	Grey mottles (2–50%) occur between topsoil and 80 cm, or grey colours are dominant (> 50%) between topsoil and 60 cm and overlie yellow, brown or red colours, or grey colours are dominant (> 50%) below 60 cm. Texture can vary widely[1]. *Leptospermum* and *Melaleuca* spp. commonly occur as a scrubby understorey together with *Gahnia* spp. Scattered *Juncus* may also be present.
Poorly drained	Grey colours are dominant (> 50%) between topsoil and > 60 cm. Textures can vary widely[2]. Dense stands of *Leptospermum* and *Melaleuca* or thick covers of *Juncus* are common. Buttongrass may also occur in places.
Very poorly drained	Peat or highly organic loamy topsoils overlie grey (or blue / green) dominant colours in lower layers. Texture can vary widely. Buttongrass is often dominant.

[1] Includes texture-contrast soils with bleached subsurface layers overlying grey-mottled clayey subsoils.
[2] Abundant gravelly iron oxide nodules / concretions may occur in soils on dolerite or basalt.

in subsurface layers rather than dominant grey mottles. Where the abundance of gravelly nodules / concretions exceeds 50% in any subsurface layer and overlies grey mottled clays, then record drainage as poor.

- *Nutrient availability*

Nutrient availability is preferably assessed from laboratory analysis (total P and total N) of surface soil samples (0–10 cm). Where analytical results are not available, then nutrient availability can be assessed from geology, soil profile features and vegetation type. Under dry eucalypt forest (or woodland) and sedgeland / heathland, nutrient availability is low in soils on all rock types (including aeolian dune sands) apart from basalt. Under wet forest (including rainforest, mixed forest, damp and wet eucalypt forest, swamp forest), nutrient availability is generally rated as medium–high on all rock types except quartzite, chert and conglomerate, which have low ratings. However, on any rock type, soils under wet forest with grey-coloured, compact pans or bleached sandy or silty subsurface layers or with many (> 50%) quartz gravels / stones in upper layers are also rated as low. Soils that have been regularly fertilised (improved pastures, annual or perennial agricultural / horticultural crops) are rated as medium to high for nutrient availability, irrespective of geology or soil profile features. Ratings for nutrient availability in relation to rock type and soil profile features are detailed in Laffan (2000). Use the codes listed in Appendix 2.

STEP 5. Determine and record site productivity class and limiting factor(s)

Site productivity class is assessed by comparing the land attributes determined during Steps 1–4 with site productivity requirements for plantations in an overall

Table 3. Assessment of site productivity class from soil and site attributes.

Soil and site attributes	Site productivity class 1 High (MAI > 20)	2 Medium (MAI 15–20)	3 Low (MAI 10–15)	4 Very low (MAI < 10)
Mean annual rainfall (mm)[1]				
Pinus radiata	> 800	600–800[2]	600–800	< 600
Eucalyptus globulus	> 850	700–850[2]	700–850	< 700
Eucalyptus nitens	> 1000	850–1000[2]	850–1000	< 850
Altitude (m)				
Pinus radiata	< 600	–	600–700	> 700
Eucalyptus globulus	< 300[3]	–	300[3]–600	> 600
Eucalyptus nitens	< 600[4]	–	600–850	> 850
Effective root depth (cm)	> 80	45–80	20–45	< 20
Soil rock (%)	< 30	30–50	50–90	> 90
Drainage class	Rapidly, well, moderately, well drained	Imperfectly drained	Poorly drained	Very poorly drained
Nutrient availability	Medium – high, medium, or total P > 100 ppm and total N > 0.1%	(Same as for Class 1)	Low, or total P < 100 ppm and total N < 0.1%	–

[1] Mean annual rainfall for very stony, shallow or coarse sandy soils will need to be downgraded to allow for their very low water-holding capacity. (See Laffan 1997.)
[2] Only for sites where native vegetation is / was damp eucalypt forest. Where native vegetation is / was wet forest, upgrade rating of Site Productivity Class to 1.
[3] Limit is 400 m in milder coastal areas.
[4] Limit is 850 m in north-eastern Tasmania on sheltered sites with good air drainage.

rating matrix (Table 3). The ratings assume that standard site cultivation (ripping and mounding) is carried out followed by fertilisation of seedlings soon after planting. The most limiting land attribute determines the productivity class. For example, a deep (> 80 cm), well-drained soil with 40% stones in the profile and medium to high nutrient availability occurring at an altitude of 200 m under a mean annual rainfall of 1000 mm would be rated as Site Productivity Class 2. In this example, stoniness is the most limiting land attribute out of the six assessed in Table 3. Because of species differences in tolerances to low temperatures and rainfall, separate ratings for *Pinus radiata*, *Eucalyptus globulus* and *E. nitens* are given for these attributes in Table 3. For Classes 2, 3 and 4, record the major limiting factor(s). Where appropriate, more than one limiting factor may be recorded. Note that Productivity Classes 2 and 4 do not have nutrient availability limitations.

Assessing site suitability for plantations

STEP 6. Determine fertiliser requirement

Fertiliser requirement is a subjective assessment of the relative amounts of fertiliser and frequency of application required for high productivity. It is based on nutrient availability and nutrient retention (capacity of the soil to retain added nutrients against losses caused by leaching). The rating for fertiliser requirement is used mainly to

Table 4. Fertiliser requirement in relation to site productivity and soil properties.

Site productivity class and soil properties	Fertiliser requirement			
	Low	Medium	High	Very high
Site productivity class	1, 2	(part 3N)	(part 3N)	(part 3N)
Nutrient availability	Medium–high, medium	Low	Low	Low
Soil texture and thickness of bleached sandy (A2) layers	Loamy or clayey soils without bleached sandy layers	Loamy or clayey soils, or soils with bleached sands < 60 cm thick over loams or clays	Soils with bleached sands 60–80 cm thick over loams, clays, pans or bedrock, or deep aeolian sands with bleached layers < 80 cm thick[1]	Bleached sands > 80 cm thick[2]

[1] Soils with medium or medium–high nutrient availability are rated as having a medium fertiliser requirement.

[2] Soils with medium or medium–high nutrient availability are rated as having a high fertiliser requirement.

differentiate soils with low nutrient availability to help decide their suitability for planting. Soils with low nutrient levels (Productivity Class 3N) will invariably need secondary fertilisation with repeated applications to achieve acceptable tree growth. The frequency of application of fertiliser will depend largely on the nutrient retention properties of these soils. For example, deep (> 80 cm) bleached sands will have a very high fertiliser requirement due to very low nutrient retention. Conversely, loamy or clayey soils with low nutrient levels will have a lower fertiliser requirement because of their much higher nutrient retention. Use Table 4 to determine a rating for fertiliser requirement. It should be noted that even soils with medium levels of nutrients may need secondary fertilisation for high productivity.

STEP 7. Record site features associated with trafficability/soil workability (slope angle, surface rock)

- *Slope angle*

Determine slope at right angles to the contour using a clinometer and record as per cent slope.

- *Surface rock*

Estimate visually within a radius of five metres the per cent cover of surface rock, including floaters greater than 2 mm and exposed bedrock (fixed rock). Record size of dominant and subdominant rocks and total per cent cover using the classes given in Appendix 2.

STEP 8. Record site features associated with flood and landslide risk (landform)

Record landform using one of the codes in Appendix 2. Floodplains and drainage depressions generally indicate sites prone to periodic flooding. Where these landforms occupy a significant proportion of sites, then the frequency, depth and duration of flooding should be investigated. Where landslide features are recognised, then provide details in the comments section of the recording sheet on the type of landslide (slump, slip, earthflow), its size (approximate length, breadth and depth) and activity status (active, inactive but relatively recent, inactive and very old). Landslide debris / scars indicate current or previous slope instability

Table 5. Erosion risk in relation to erodibility, slope class and rainfall intensity.

Soil erodibility rating	Slope class	Erosion risk rating[1]
Low	< 30%	Negligible (low)
	> 30%	Low (moderate)
Moderate	< 30%	Low (moderate)
	> 30%	Moderate (moderate to high)
Moderate to high[2]	< 30%	Moderate (moderate to high)
	> 30%	Moderate to high (high)
High[3]	< 25%	Moderate to high (high)
	> 25%	High (very high)
Very high[3]	< 20%	High (very high)[4]
	> 20%	Very high (extremely high)

[1] Refers to erosion risk by rainfall and runoff. See footnotes 2 and 3 for wind erosion risk. Ratings in parentheses refer to sites with high frequency of intense rainfalls (north-eastern coastal area).

[2] Soils on sand flats with moderate–high erodibility by wind are rated as having moderate wind erosion risk.

[3] Soils on sand dunes with high or very high erodibility by wind are rated as having high wind erosion risk.

[4] Rating is very high (extremely high) along drainage lines and watercourses.

and need to be investigated by a soils or geotechnical specialist. The presence of seepages or soaks may also indicate potential landslide sites and they require further investigation by a specialist.

STEP 9. Determine soil erodibility class and erosion risk from soil and site features

Determine erodibility class using Appendix 3 and record one of the codes in Appendix 2. Where evidence of erosion occurs, record details of type (rills, gullies, sheetwash) and severity (per cent area affected and depth of soil loss) in the comments section of the recording sheet. Determine erosion risk using Table 5.

STEP 10. Determine and record site suitability class and limiting factor(s)

Assess the rating of site suitability for plantations using productivity class and soil and site features (Table 6). Record site suitability as S (suitable), M (marginally suitable) or U (unsuitable), together with limiting factor(s) for marginal and unsuitable ratings. More than one limiting factor can be recorded where appropriate. Use the codes in Appendix 2.

Sites suitable for plantations must have Site Productivity Class 1 or 2 (or Class 3N soils with medium rating for fertiliser requirement) and satisfy all the other criteria listed under the 'suitable' heading. On an area basis, at least 70% of a compartment should be rated as suitable. Marginally suitable and/or unsuitable sites adjacent to the boundaries of compartments or where they cover manageable areas (> 5 ha) inside compartments should be excluded from plantation development. Marginally suitable sites have either Site Productivity Class 3 (including 3N soils with high

Table 6. Assessment of site suitability class for plantations.

Site productivity class and soil and site features	Site suitability class suitable (S)	marginally suitable (M)	unsuitable (U)
Site productivity class	1, 2, (part 3N)	3 (part 3N)	4, (part 3N)
Fertiliser requirement	Low, medium	High	Very high
Slope angle (%)	< 30	30–40	> 40
Surface rock (% cover)[1]			
Bedrock	< 10	10–30	> 30
Boulders (> 60 cm)	< 30	30–50	> 50
Stones / cobbles (6–60 cm)	< 50	50–80	> 80
Gravels (0.2–6 cm)	< 80	–	> 80
Flood risk	Landforms not susceptible to flooding	Floodplains, depressions with low flood frequency	Floodplains, depressions with high flood frequency
Landslide risk	Stable landforms not susceptible to movement, talus deposits with low susceptibility	–	Landslide debris / scars and adjacent slopes highly susceptible to movement
Erosion risk	Negligible, low, moderate, moderate to high	High	Very high, extremely high

[1] Adapted from Clarke and Fogarty (1999).

fertiliser requirement) or else have Site Productivity Classes 1 or 2 (or Class 3N soils with only medium fertiliser requirement) but satisfy one or more of the other criteria listed under the 'marginally suitable' heading. Unsuitable sites have either Site Productivity Class 4 (or Class 3N soils with very high fertiliser requirement) or else have higher site productivity but satisfy one or more of the other criteria listed under the 'unsuitable' heading.

For soils with low nutrient availability (Productivity Class 3N) and rated as being suitable (S) or marginally suitable (M-Q), a tree-nutrition specialist must be consulted to prescribe appropriate fertilisers and to verify the economics of the fertilisation program before proceeding with plantation development.

Example of a completed field sheet

The bottom half of Appendix 1 has been filled out as an example of how to encode soil and site features and assess site productivity and suitability for plantations. Plots 1 and 2 occur on undulating (3–8%) hill slopes at an elevation of about 300 m where mean annual rainfall lies between 1400 mm and 1600 mm. The native vegetation is mixed forest with an overstorey of *Eucalyptus obliqua* or *E. regnans* and myrtle (*Nothofagus cunninghamii*). Shrub species are dominated by native pear (*Pomaderris apetala*) and musk (*Olearia argophylla*) with a ground cover of mosses or cutting grass. In plot 1, the rock type is Permian mudstone, with a well-drained gradational soil profile characterised by shallow brown loams overlying yellow and orange clays to depths below 80 cm. The effective root depth (ERD) exceeds 80 cm and soil rock is less than 30%. Because the vegetation is mixed forest and there are no bleached subsurface soil layers, the nutrient availability class is assessed as medium–high. From Table 4, the fertiliser requirement is assessed as low, as is the rating for soil erodibility (Appendix 3). Using Table 5, the erosion risk rating is assessed as negligible. Working through the soil and site attributes in Table 3, it can be seen that plot 1 satisfies all the requirements for Site Productivity Class 1. Similarly, plot 1 is classified as being suitable for plantations because it satisfies all the requirements of the Suitable Class listed in Table 6.

In plot 2, where the substrate is Permian sandstone, the soil profile is dominated by deep (> 80 cm), bleached quartz sands with orange mottling at depths below 40 cm. The nutrient availability class is assessed as low and fertiliser requirement (Table 4) is rated as very high. Appendix 3 indicates that these soils are highly erodible. Using Table 3, plot 2 keys out as having low productivity due to low levels of nutrients (Class 3N). From Table 6, it can be seen that, because of a very high fertiliser requirement, the site is unsuitable (U-Q) for plantations.

Plots 3 and 4 are on rolling (10–15%) hill slopes developed in Jurassic dolerite at elevations of 650 m and 500 m respectively on the flanks of the Central Plateau. The sites are sheltered, with good drainage of cold air, and the mean annual rainfall range is 1200–1300 mm. The native vegetation is damp eucalypt forest dominated by *Eucalyptus obliqua* and *E. delegatensis* with an understorey of mainly stinkwood and blanket bush. The ground cover comprises bracken fern, cutting grass and hard ferns. The soils in both plots are well drained and are assessed as having medium to high nutrient availability and low fertiliser requirement. Plot 3 has a deep (> 80 cm) loamy and clayey profile, whereas, in plot 4, dolerite floaters were struck at a depth of 20 cm. Reference to Table 3 shows that plot 3 classifies as medium productivity (Class 2T) for *E. nitens* but has low productivity (Class 3T) for *E. globulus* and *Pinus radiata* due to adverse temperatures at altitudes above 600 m. Because of more than 50% soil rock, plot 4 is classified as having low productivity (Class 3S). From Table 6, it can be seen that plot 3 is classified as being marginally suitable (M-C) and plot 4 as unsuitable (U-C) for plantations due to abundant surface rock which would severely limit trafficability and soil workability.

Use of the field method in Tasmania

Since early 1997, nearly 30 staff from the five Forest Districts in Tasmania have been instructed on how to use the method. In each training session normally spread over two days, four or five people are instructed in the field on the following aspects: how to navigate in the forest using compass and hip-chain; the correct technique for using soil augers; how to measure and record the various soil and site attributes, and how to interpret the information and derive ratings of site productivity and suitability. Most trainees have also subsequently attended an introductory, one-day course on Tasmanian forest soils, which is aimed at providing participants with basic skills and knowledge of the formation and properties of soils, the identification of a range of Tasmanian forest soils and land attributes affecting site selection for plantations. The Forestry Tasmania Soils Specialist also carries out regular field visits to each District to help with any local problems and provide further instruction where necessary.

Field work is normally carried out by a crew of two operators, with one navigating and making auger borings and the other recording and interpreting the data. Time taken to auger the soil and record and interpret the data varies between about five to ten minutes, depending mainly on hardness and rockiness of the soil. Moist soils are much quicker and less tiring to auger than dry soils. As would be expected, the total number of observations of land attributes that can be completed in a day is also highly dependent on the ease of access. In forest with a thick, scrubby understorey requiring use of a slash-hook, between 15 to 20 sites (30 to 40 ha at an intensity level of one observation every two hectares) can comfortably be completed by one crew. In open forest and cleared land, the coverage can easily be doubled. On cleared land with easy topography, consideration is given to mechanically excavating soil pits because this enables more accurate determination of rock content and any limitations to root depth.

The field sheets are collated in the office and a summary is prepared for each compartment showing the proportions of site productivity and suitability classes, together with other attributes such as substrates and slope angles. In most Districts, the soil and site attributes are entered into a database. Maps at a scale of 1:10 000 are also produced showing the location of each observation site, together with the ratings and limiting factors of site productivity and suitability. This information is used to help decide whether a compartment should be wholly or partly planted or regenerated, or whether to use different management systems on the one compartment. For example, a compartment that has areas of both high and medium productivity may be recommended for pruning for clearwood on the highly productive part, and for a pulpwood regime on the area of medium productivity. Currently, compartments are identified as potential plantations where about 70% of the total observations are classified as suitable using Table 6.

Future applications could include the computerisation of the data-recording and interpretive stages. So far, sheets for recording and interpreting land attributes have been found to be easy and convenient to use in the field. However, use of small, weatherproof electronic data recorders or hand-held computers to directly record and interpret information in the field would overcome the requirement of having to later enter the information manually into a database.

Results from the field method are also being used to extend Forestry Tasmania's soil database. Periodic review of the field sheets and communication with survey crews by the Soils Specialist allows recognition of soils not previously characterised during the mapping project carried out between 1990 and 1995 (Laffan and Neilsen 1997). These new soils are then identified in the field, photographed, and sampled for full characterisation. The information is added to the database and is subsequently disseminated to the Districts by holding field days to discuss the recognition and use of the soils.

Summary and conclusions

The field method described relies on carrying out transects to make observations of basic soil and site attributes at predetermined intervals. The sampling intensity of observations is adjusted to suit the complexity of the terrain and soil pattern. It is considered that the recommended standard of one observation-site every two hectares is sufficiently precise to account for most of the expected natural variation in environmental factors. The land attributes are recorded onto field sheets and then interpreted using a series of tables to derive ratings of site productivity and suitability for hardwood (*Eucalyptus globulus* and *E. nitens*) and radiata pine plantations. It is a rapid procedure using minimal field equipment and can be carried out by ‘non-specialist’ personnel following a short period of training. Although it was designed for use in native forests, the method can also be used on other sites such as farmland or scrubland. The method is being used in Tasmania on both State forest and private land as an essential planning tool in the selection of sites for plantations. In addition to determining whether sites could be planted or should be regenerated, the method allows the prescription of different silvicultural practices, such as clearwood or pulpwood regimes in the same compartment. Because the method specifies any limiting soil and/or other land factors, management practices to ameliorate limitations can be prescribed where appropriate.

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Appendix 1. Field sheet for recording land attributes and assessing site productivity/suitability for plantations.

Planned Coupe/Block ______ Assessed By ______ Date ___/___/___ Rainfall ______ Elevation Range ______

Site No.	Prod. Class & Limit. Factor	Suit. Class & Limit. Fact.	Soil Profile	Rock Type	ERD	Soil Rock %	Drain. Class	Nutr. Class	Fert. Req.	Slope %	Lu & Form	Surface Rock: Dom. Size	Surface Rock: Sub. Size	Surface Rock: Total %	Soil Erod Class	Dess Risk	Vegetation: Type	Vegetation Species: Trees	Vegetation Species: Shrub	Vegetation Species: Ground
Comments																				
Comments																				
Comments																				
Comments																				
Comments																				
Comments																				
Comments																				
1	1	S	Br 10 Lo / Y 30 CL / O (G) 80 C	Pc	750	<30	W	MH	L	3	HSL	—	—	—	L	N	M	GS MY	A	C
Comments: Rainfall 1400-1600mm Elevation : 300m																				
2	3N	U-Q	Br 5 Lo / G 40 S / G(a) 80 S	Ps	750	<30	I	L	VH	8	HSL	—	—	—	H	MH	M	QE MY	A	M
Comments: Rainfall : 1400-1600mm Elevation : 300m																				
3	3T	M-C	DBr 40 Lo / Br 80 C	3d	750	<30	W	MH	L	10	HSL	B	S	30/50	L	N	T	GS DC	A	H
Comments: Rainfall : 800 - 1300mm Elevation : 650m																				
4	3S	U-C	DBr 30 Lo / on FLOATERS	3d	—	750	W	MH	L	15	HSL	B	S	50/80	L	N	T	GS DC	A	BC
Comments: Rainfall : 1200- 1300mm Elevation : 300m																				

PRODUCTIVITY RATING AND LIMITING FACTORS

Record as one of the following: **1, 2, 3, or 4**. Assess using **Table 3.**

For productivity ratings 2, 3 and 4, record one or more of following codes for limiting factors:
D – drainage, **N** – nutrients, **R** – effective root depth, **S** – soil rock, **T** – altitude, **P** – rainfall.

SUITABILITY RATING AND LIMITING FACTORS

Record as one of the following: **S**, **M** or **U**. Assess using **Table 6.**

For suitability ratings **M** and **U**, record one or more of the limiting factor codes used above for Productivity (except **N**) and / or one or more of the following:

Q – fertiliser requirement, **A** – slope, **C** – surface rock, **F** – flood risk, **L** – landslide risk, **E** – erosion risk.

Use a hyphen between limiting factors and suitability class, e.g. M-AE, U-D.

SOIL PROFILE FEATURES

SOIL COLOUR:	**Y** – yellow, **Br** – brown, **O** – orange, **G** – grey, **Re** – red, **R** – rusty, **W** – white, **B** – black, **L** – light, **D** – dark. (Put mottled colours inside brackets.)
SOIL TEXTURE:	**S** – sandy, **Lo** – loamy (**SLo** – sandy loam, **ZLo –** silty loam, **CLo –** clay loam), **C** – clayey, **P** – peaty, **H** – humic.
PANS:	**HP** – hardpan (compacted or cemented layer difficult to auger even when moist).
DEPTH:	Numerical entry down to 80 cm or to impeding layer if shallower.

ROCK TYPE

Prq	Precambrian quartzite	**Dg**	Devonian granite
Prsl	Precambrian slate	**Db**	Devonian quartz sandstone and mudstone
Prm	Precambrian mudstone, siltstone	**Pc**	Permian conglomerate, tillite, mudstone, siltstone
Prs	Precambrian sandstone, slate and phyllite	**Ps**	Permian sandstone
Prsc	Precambrian schist	**Trs**	Triassic sandstone
Prd	Precambrian dolomite	**Jd**	Jurassic dolerite
Cm	Cambrian interlayered mudstone, siltstone, sandstone	**Tb**	Tertiary basalt
Cg	Cambrian greywacke, sandstone, siltstone and mudstone	**Tc**	Tertiary clay, gravel and sand
Cbv	Cambrian basic volcanics	**Qb**	Quaternary basalt talus
Civ	Cambrian intermediate volcanics	**Qd**	Quaternary dolerite talus
Cc	Cambrian chert	**Qa**	Quaternary alluvial deposits
Ol	Ordovician limestone	**Qs**	Quaternary aeolian sands
Oc	Ordovician conglomerate		
Os	Ordovician sandstone		
Sds	Silurian–Devonian sandstone, siltstone, slate		

EFFECTIVE ROOT DEPTH (ERD)

See **Table 1**. Record to nearest 5 cm. If no limiting layer within 80 cm then record as > 80.
If soil rock (floaters) impedes auger penetration to 80 cm then do not record a depth for ERD (insert a '–' in box) but estimate soil rock content as described below.

SOIL ROCK (gravels, cobbles, stones, boulders below soil surface)

See **Step 4., part 2.** If auger strikes rock at depths < 25 cm, carry out 5 further augers; 25–45 cm carry out 2 further augers within 5 m radius and use deepest auger bore to record soil rock content as follows: > 50% where depth < 25 cm, 30–50% where depth is 25–45 cm, < 30% where depth is 45–80 cm.

DRAINAGE CLASS

See **Table 2**. Record one of the following classes: **R** – rapidly drained, **W** – well drained, **MW** – moderately well drained, **I** – imperfectly drained, **P** – poorly drained, **VP** – very poorly drained.

If soil rock prevents auger penetration into subsoil then do not record drainage (insert a '–' in box).

NUTRIENT AVAILABILITY

See **Table 3**. Record one of the following classes: **L** – low, **M** – medium, **MH** – medium to high.

FERTILISER REQUIREMENT

See **Table 4**. Record one of the following classes: **L** – low, **M –** medium, **H** – high, **VH –** very high.

SLOPE

Record % slope at right angles to contour.

LANDFORM

HSL – hillslope, **HCR** – hillcrest, **MSL** – mountain slope, **PLT** – plateau surface, **SCA** – scarp, **LDS** – landslide debris / scar, **SCR** – scree, **FTS** – footslope, **SPR** – spur, **GUL** – gully, **FAN** – fan, **VLF** – valley flat, **DDE** – drainage depression, **SWP** – swamp, **FLP** – floodplain, **TER** – terrace, **DUN** – dune, **SDF** – sand flats.

SURFACE ROCK

Estimate visually within 5 m radius. Record one of the following size classes for both dominant and subdominant rocks on soil surface:
G – gravels (0.2–6 cm), **C –** cobbles (6–20 cm), **S** – stones (20–60 cm), **B** – boulders (> 60 cm), **F -** fixed rock.

Record one of the following classes (%) for total surface rock cover:
< 10, 10–30, 30–50, 50–80, > 80.

ERODIBILITY CLASS AND EROSION RISK

Erodibility class — see **Appendix 3**. Record one of the following classes: **L** – low, **M** – moderate, **MH** – moderate–high, **H** – high, **VH** – very high.

Erosion risk — see **Table 5**. Record one of the following classes: **N** – negligible, **L** – low, **M** – moderate, **MH** – moderate–high, **H** – high, **VH** – very high, **EH** – extremely high.

VEGETATION

Type

P – swamp forest, **R** – rainforest, **M** – mixed forest, **W** – wet eucalypt forest, **T** – damp eucalypt forest, **D** - dry eucalypt forest, **O** – woodland, **S** – scrub (shrubs 2–8 m tall), **H** - heath (shrubs < 2 m tall), **G** – native grassland / herbfield, **A** – hardwood plantation, **F** – softwood plantation, **I** – improved pasture, **U** – unimproved pasture, **C –** agricultural / horticultural field crops, **V –** vineyards, orchards.

Tree species

OB	*E. obliqua*
RE	*E. regnans*
DE	*E. delegatensis*
AM	*E. amygdalina*
GL	*E. globulus*
NI	*E. nitens*
VI	*E. viminalis*
DA	*E. dalrympleana*
NT	*E. nitida*
OV	*E. ovata*
SI	*E. sieberi*
JO	*E. johnstonii*
GU	*E. gunnii*
PA	*E. pauciflora*
CO	*E. coccifera*
RU	*E. rubida*
CD	*E. cordata*
PU	*E. pulchella*
SB	*E. subcrenulata*
TE	*E. tenuiramis*
WA	Silver wattle
BL	Blackwood
MY	Myrtle
SA	Sassafras
LE	Leatherwood
CT	Celery-top pine
KB	King Billy pine
HU	Huon pine

Shrub species groups

A	Native pear / musk / lancewood, usually with stinkwood, wallaby wood, blanket bush, Christmas bush, manfern, native laurel.
B	Blanket bush, often with dwarf musk, prickly beauty.
C	Pepper bush / geebung usually with native currant, waratah.
D	Dolly bush, often with blanket bush, native fushia, pinkwood, prickly mo, native willow.
E	Stinkwood / lancewood / cheeseberry, usually with native laurel, pepper bush, drooping mimosa.
F	Tall scrub at wet sites other than A, B, C, D, E, H, M, T or W.
G	Dry sclerophyll, honey suckle / sheoak, native cherry, prickly mo, native hop, *Hakea*, native willow, *Banksia*.
H	Horizontal
K	Blackboy
L	Short-leaved shrubs, e.g. bitter leaf, parrot bush.
M	Manfern
P	Short pricklies, e.g. golden pea, parrot pea, heaths, guitar plant, native daphne, native gorse, bitter leaf.
T	Tea trees (*Leptospermum*), paper bark(*Melaleuca*), *Callistemon*.
W	Native willow
N	No shrubs

Ground species groups

A	Bauera
B	Bracken and herbs
C	Cutting grass, often with wet ferns
F	Fireweeds, often with liverworts
G	Grass and herbs (not cutting grass or sword grass)
H	Hard ferns: leech fern, cathead fern
K	Buttongrass
M	Mosses and liverworts
S	Sword grass, saggs, rushes
W	Wet ferns: soft bracken, lady fern
BB	Blackberry
R	Ragwort
GO	Gorse

Appendix 3. Soil erodibility class in relation to geology, soil properties and native vegetation.

Geology, soil properties and native vegetation type	Erodibility class[1,2]
Precambrian quartzite	
– Rapidly / well-drained soils with bleached* sandy layers under scrub / heath or dry / wet forest.	H
– Poorly / very poorly drained organic soils under scrub and sedgeland / heathland.	MH
Precambrian slate	
– imperfectly to poorly drained shallow loamy soils under wet forest.	MH
Precambrian mudstone	
– imperfectly drained grey and brown mottled soils under wet forest.	MH
Precambrian sandstone, slate and phyllite	
– well / moderately well-drained soils with bleached* sandy layers under dry forest.	H
– well-drained clayey soils with / without bleached* loamy layers under wet forest.	M
Precambrian schist	
– moderately well-drained clayey soils with distinct worm mixing in subsoils under dry forest.	M
– well-drained soils with bleached* sandy layers under dry forest.	MH
Precambrian dolomite	
– imperfectly drained loamy soils with compact pans under wet forest.	H
Cambrian interlayered mudstone, siltstone and sandstone	
– imperfectly / poorly drained grey fine sandy / loamy soils with compact pans under wet forest.	H
– well-drained clayey soils under wet forest.	L
Cambrian greywacke, sandstone, siltstone and mudstone	
– imperfectly / poorly drained clayey soils under wet scrub.	MH
– moderately well-drained soils with bleached* sandy layers under wet forest.	MH
– well-drained clayey soils under wet forest.	L
Cambrian basic and intermediate volcanic rocks	
– well-drained red and brown clayey soils under wet forest.	L
Cambrian chert	
– imperfectly drained soils with bleached* sandy pans under damp forest.	H
– moderately well-drained gradational soils under wet forest.	L
Ordovician limestone	
– moderately well-drained soils with bleached* fine sandy / loamy layers under wet forest.	MH
– well-drained clayey soils under wet forest.	L
Ordovician conglomerate	
– imperfectly drained soils with bleached* sandy layers under dry / damp forest.	H
– well-drained pale-coloured sandy soils under heathy to scrubby dry forest.	H

Geology, soil properties and native vegetation type	Erodibility class[1,2]
Ordovician sandstone	
– moderately well / imperfectly drained soils with bleached* sandy layers under dry forest.	H
– well-drained clayey soils under wet forest.	L
Silurian-Devonian sandstone, siltstone, slate (Mathinna Beds)	
– moderately well-drained soils with bleached* sandy layers under dry forest.	H
– moderately well / imperfectly drained soils with distinct worm mixing in subsoils under dry forest.	MH
– well / moderately well-drained clayey soils under dry or wet eucalypt forest.	M
– well-drained loamy / clayey soils under mixed forest / rainforest.	L
Devonian granite	
– well / moderately well / imperfectly drained soils with bleached* sandy layers under dry forest.	H
– well / moderately well / imperfectly drained soils with bleached* sandy layers under wet forest.	MH
– well-drained loamy soils under wet eucalypt / mixed forest / rainforest.	M
– well-drained deep, dark-coloured loamy soils under damp / wet forest.	M
– well-drained clayey soils under wet forest.	L
Devonian quartz sandstone and mudstone	
– imperfectly drained grey and yellow mottled soils under wet forest.	MH
Permian conglomerate, tillite, mudstone and siltstone	
– imperfectly drained clayey soils with distinct worm mixing in subsoils under dry forest.	MH
– moderately well-drained soils with bleached* fine sandy layers under dry forest.	MH
– well-drained loamy / clayey soils with / without pale-coloured subsurface layers under dry forest.	M
– imperfectly drained grey and brown mottled soils under wet forest.	MH
– well-drained clayey soils under wet forest.	L
Permian and Triassic sandstone	
– well / moderately well / imperfectly drained soils with bleached* sandy layers under dry or wet forest.	H
– poorly drained sandy / loamy soils under dry or wet forest.	MH
– well-drained loamy / clayey soils under wet forest.	M
Jurassic dolerite and derived Quaternary talus	
– imperfectly drained loamy over brown and grey mottled clayey soils under dry forest.	MH
– poorly drained loamy / clayey soils under dry or wet forest.	MH
– well / moderately well-drained red soils under dry forest.	M
– imperfectly drained brown and grey mottled clayey soils under wet forest.	M
– well-drained red / brown clayey soils under wet forest.	L
Tertiary basalt	
– well-drained red / brown loamy / clayey soils under dry or wet forest.	L

Geology, soil properties and native vegetation type	Erodibility class[1,2]
Tertiary clay, sand, gravel	
– rapidly / well / moderately well-drained soils with bleached* sandy layers under dry forest.	H
– well / moderately well / imperfectly drained clayey soils under dry or damp or wet forest.	M
Quaternary basalt talus	
– well / moderately well-drained brown clayey soils under wet forest.	L
Quaternary alluvial deposits	
– well / rapidly drained deep coarse sandy soils from granite under dry forest.	VH
– well / moderately well / imperfectly drained loamy / clayey soils under dry / wet forest.	M
– poorly / very poorly drained sandy / loamy / clayey soils under scrub / sedgeland / heathland.	MH
– poorly drained clayey / loamy / fine sandy soils under blackwood swamp.	M
Quaternary aeolian sands	
– Rapidly drained yellow / brown sandy soils with / without bleached layers under dry coastal scrub.	H[3]
– Rapidly drained deep, very recent sands under dry coastal scrub or grassland, or mobile sands.	VH[3]
– Well / moderately well / imperfectly / poorly drained sandy soils on sand flats.	MH[3]
Quaternary aeolian sands overlying Jurassic dolerite (or mixed Triassic / Permian sandstone and dolerite)	
– well / moderately well-drained sandy loams overlying brown / red clays under dry or wet forest.	M
– poorly drained grey sandy loams overlying brown mottled clays under dry or wet forest.	MH
– well / moderately well-drained soils with bleached* sandy layers under dry or wet forest.	H

[1] Refers to erodibility by rainfall and runoff apart from soils on Quaternary aeolian sands (footnote 3). Key to codes; L = Low, M = moderate, MH = Moderate to high, H = High, VH = Very high.

[2] Decrease rating by 1 class (e.g. from H to MH, from MH to M, etc.) for very stony soils (> 50% stones).

[3] Erodibility by wind.

* Bleached includes white, light grey, light yellow or light brown.