Soil-observation strategies for assessing plantation potential in Circular Head District, north-western Tasmania

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Abstract

A method is described for inspecting forest soils in the Circular Head District to assess site productivity and suitability for plantations. The areas investigated are located on easy sloping (< 30%), hilly terrain, with negligible rock outcrop or surface boulders. All have relatively high mean annual rainfall (> 1200 mm).

The main soil attributes affecting plantation potential are soil depth and drainage. Using hand augers, field observations of soil colour, including mottling, and depth to an impeding layer (bedrock, compact pan) are recorded along transects. Soil colour patterns are used to infer soil drainage class. The soil information is used to determine a rating of site productivity for each observation site. The proportions of these ratings largely determine whether a coupe could be planted or must be regenerated. A sampling outcome with significant proportions (about 70% or more) of high (Class 1) and/or medium (Class 2) ratings of site productivity clearly identifies a coupe as potential plantation.

The number and intensity of observations are dependent largely on ease of access. Observation density is higher in logged coupes where good road access and a network of snig tracks allow relatively rapid progress. The soil-observation interval along transects varies between 50 and 150 m and is similar for both logged and unlogged coupes, but the interval between transects is much closer in logged coupes. Mean soil-observation density for unlogged coupes (1612 ha) assessed between January and December 1997 was about one observation every 4 ha. In contrast, logged coupes (1875 ha) assessed between July and December 1997 had a mean observation density about twice that of the unlogged coupes (one observation every 2 ha). Analysis of the data shows that, of the total area of mainly marginal land assessed (3487 ha), 20 coupes covering 1243 ha (36%) are suitable for plantations. The work was carried out by local staff after a short period of training by a soils specialist.

The soil-observation strategies used in the Circular Head District allow a systematic and reasonably precise assessment of plantation potential in an area characterised by highly variable and complex soil patterns. The strategies were developed specifically for soils limited only by depth and drainage characteristics. However, the methodology can readily be adapted to assess plantation potential in areas where slope steepness, surface rock, elevation, mean annual rainfall, erosion and flood hazards may be other inhibiting factors.

Introduction

The establishment of both softwood and hardwood plantation forests in Tasmania is predicted to increase markedly in the near future. Recent economic evaluations of hardwood plantations in Tasmania (Gerrand *et al.* 1993; Candy and Gerrand 1997) have highlighted the importance of site selection in determining potential profitability. Similar conclusions are likely to apply to softwood plantations.

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A systematic and objective methodology for assessing site productivity and suitability for plantations using land resource information has recently been developed for Tasmania (Laffan 1994, 1997). The methodology takes account of various biophysical attributes including soil, topography and climate.

State forests in northern Tasmania covered by the 1:50 000 scale, soil-mapping project (Laffan and Neilsen 1997) have been assessed and classified for site productivity and suitability for plantations. Maps showing these interpretations have also been produced. Elsewhere in the State, numerous small forest compartments have been assessed at various times over the last five years. Since 1995, the assessment of site suitability has been carried out sporadically by the Senior Soil Scientist from the Forest Practices Board, following specific requests by District staff from Forestry Tasmania. More recently, the demand for information on site suitability has increased significantly in response to the projected upturn in plantings.

In late 1996, part of a large block of unlogged State forest near Mawbanna in the Circular Head District was inspected by the Senior Soil Scientist (Forest Practices Board) and the District Forester to determine the feasibility of carrying out more detailed assessments of site suitability. During this reconnaissance inspection, it was realised that because of the complexity of the soil patterns and high variability in site productivity, even over short distances, the intensity of site observations would have to be much higher than normal to allow objective decisions on whether or not to plant. Because of the limited availability of the Senior Soil Scientist to carry out further extended field work, it was decided to pursue an alternative approach using local staff from Circular Head District. The strategy involved training tree measurers in the basics of soil recognition and assessment of site suitability for plantations so that they could then work in the field independently to carry out a programme of intensive soil observations and interpretations of plantation potential.

Following the investigations in the Mawbanna area, further soil observations and assessment of plantation suitability were carried out in numerous logged coupes elsewhere in the Circular Head District. This paper outlines the methods and sampling strategies adopted to determine plantation potential in unlogged forests in the Mawbanna area (Black River, Tipunah, Crayfish and Dip blocks), and in logged coupes (Togari, Christmas Hills, Redpa, Salmon River, Newhaven, Nabageena, Meryanna, Frankland, Sumac and Temma blocks) to the south and west of Mawbanna.

Methods

Study area

The unlogged blocks assessed near Mawbanna between January and December 1997 total approximately 1600 ha and are located about 45 km south-east of Smithton. Soil-forming substrates are dominated by Precambrian finely laminated Cowrie Siltstone (Department of Mines 1982) occurring on mainly undulating (< 10%) and rolling (10–30%) hills at altitudes below about 140 m. Mean annual rainfall lies within the range 1200–1400 mm.

Logged coupes investigated in other parts of the District between July and December 1997 total about 1900 ha and cover a range of substrates including Precambrian mudstone, Cambrian interlayered mudstone, siltstone and sandstone, and Tertiary basalt. Topography is dominated by undulating and rolling low hills, with mean annual rainfall exceeding 1200 mm.

Native vegetation and soils

Native vegetation in the Mawbanna area is diverse and includes wet eucalypt forest, mixed forest, scrub and buttongrass moorland. The vegetation pattern generally reflects marked differences in soil properties, particularly depth and drainage class. Deep (> 80 cm), well-drained soils are characterised by dark, organic-rich topsoils overlying yellowish brown and reddish brown clayey subsoils. They are similar to Farnham soils formed on Cambrian interlayered mudstone, siltstone and sandstone previously identified west of Smithton (Grant *et al.* 1995). Canopy species include *Eucalyptus obliqua* over *Pomaderris apetala* and *Olearia argophylla*. Moderately well-drained soils are somewhat similar but generally have grey mottles between the topsoil and a depth of 30 cm below the surface. Native vegetation is usually similar to that on well-drained soils.

Imperfectly drained soils include profiles with dominantly grey-coloured silty clay loams between the topsoil and depths of 30–60 cm, overlying yellow, brown or red clayey subsoils. Some imperfectly drained profiles have grey silty clay loams and silty light clays to depths below 90 cm, with hard, compact layers between 20 and 50 cm. These soils are somewhat similar to Fagan soils formed on Cambrian sedimentary rocks west of Smithton (Grant *et al.* 1995). Some profiles have abundant quartz gravels in surface and subsurface layers. Native vegetation is dominated by *Eucalyptus ovata* or *E. obliqua* with a mixed scrubby understorey of tea-tree or *Acacia mucronata*.

Poorly drained soils are usually characterised by thick, very dark loamy topsoils overlying grey and orange mottled silty light clays. Water-tables generally lie close to the surface. Native vegetation includes *Eucalyptus ovata*, blackwood, paperbark, cutting grass and manferns. Buttongrass plains are generally associated with poorly drained or poorly to very poorly drained peaty soils overlying quartzite gravels.

Similar soil and native vegetation patterns occur in logged coupes where the substrates comprise sedimentary rocks. Soils formed on Tertiary basalt are mostly deep and well drained, with red or reddish-brown colours throughout the profile. Native vegetation is mainly mixed forest (eucalypts over rainforest: Gilbert 1959), with small areas of rainforest.

Rating plantation productivity and suitability

An initial step involved the classification of plantation productivity and suitability based on soil, topographic and climatic attributes in the Mawbanna area. The soils recorded in the reconnaissance stage were considered to represent most of the range of soils likely to be encountered during more intensive field investigations. The soils were rated for site productivity and suitability according to the methodology of Laffan (1997). Site productivity is based on the assessment of five land qualities: temperature regime, moisture availability, drainage, rooting conditions, and nutrient availability. Altitude is used as a surrogate for temperature regime and, because of low elevations in the areas investigated, this attribute is not limiting for plantation growth. Likewise, because of a relatively high mean annual rainfall, moisture availability is non-limiting.

Laboratory analysis of three soils from the Mawbanna area, including a deep well-drained soil, a grey-coloured, imperfectly drained silty soil with compact pan, and a shallow soil dominated by abundant quartz gravels, showed that surface layers (0–10 cm) all had medium to high levels of total nitrogen (N) (> 0.1%) and total phosphorus (P) (> 100 ppm). On this basis, nutrient availability is not considered to be a major factor limiting plantation productivity on any of the soils from logged or unlogged coupes. However, because very low levels of P occur at depths below 10 cm in soils with compact pans and soils with a high content of quartz gravels, particular care is required during harvesting operations to prevent excessive displacement of topsoil, which could cause problems of nutrient deficiencies and poor growth.

Because of wide variations in both rooting conditions and duration of soil wetness, site productivity will be determined mainly by soil depth and drainage. Ratings of site productivity range from Class 1 (high) to Class 4 (very low). The assessment criteria

Table 1. Assessment criteria (soil depth and drainage) for rating site productivity class.

Soil drainage class	Soil depth* (cm) > 80	45–80	20–45	< 20
Well drained; moderately well drained	**1**†	**2**	**3**	**4**
Imperfectly drained	**2**	**2**	**3**	**4**
Poorly drained	**3**	**3**	**3**	**4**
Very poorly drained	**4**	**4**	**4**	**4**

* Depth to bedrock or compact, massive pan. † Figures in bold are site productivity classes.

Table 2. Drainage classes in relation to soil features.

Drainage class	Soil features
Well drained	Uniform yellow, brown or red colours below topsoil.
Moderately well drained	Grey mottles (2–50% of cut faces) occur between topsoil and 30 cm, overlying yellow, brown or red colours, or they occur at depths below 60 cm, or grey colours are dominant (> 50%) below 80 cm.
Imperfectly drained	Grey mottles (2–50%) occur between topsoil and 80 cm, or grey colours are dominant between topsoil and 60 cm, and overlie yellow, brown or red colours, or grey colours are dominant between topsoil and > 60 cm, with a compact layer (hardpan) at depths 20–50 cm.
Poorly drained	Thick, very dark-coloured topsoils overlie grey-coloured subsoils to depths > 80 cm. Orange or rusty coloured mottles may also occur.
Poorly to very poorly drained	Variable thickness of peat over quartzite gravels or over sand and quartzite gravels.

outlined in Table 1 relating site productivity to soil depth and drainage are from Laffan (1997).

Site suitability takes account of trafficability and land degradation hazards, including flooding, erosion and landslide risks, in addition to site productivity. The main factors affecting trafficability are slope angle and the occurrence of rock outcrop or surface boulders. Because these characteristics, together with land degradation hazards, are non-limiting in the areas investigated, site suitability is determined by the rating for site productivity.

Development of field record sheets

Following the establishment of plantation suitability ratings based on soil and other land characteristics, an assessment form was developed for recording site data in the field. The field record sheet includes data on both native vegetation and soils. Soil features considered to be important include colour, texture (whether peat present), thickness of soil layers, depth to hardpans or bedrock, and presence of gravels in the soil profile. Colour, depth, texture (peat) and presence of hardpans were used to infer the drainage status of the soil using the criteria given in Table 2.

Thickness of topsoil and depth at which colour patterns and pans occurred were shown diagrammatically on the field sheet. Codes were used to indicate soil colour and the presence of hardpans, peat and gravel. Plants in the canopy, understorey, and shrub and ground layers were also recorded in an attempt to more closely correlate vegetation and soils, and to elucidate any species which may indicate a particular soil type. Other data recorded included ease of soil augering (to indicate hardpans), relative stocking density of blackwood, and forest type from Forestry Tasmania PI (photo-interpretation) maps. Examples of a completed soil assessment plot sheet and codes are shown in Appendices 1 and 2.

Sampling method and intensity

The free survey method conventionally used to sample and map soils is often unsuitable on forested lands, particularly where the soil pattern is complex and access is restricted. In such areas, a point-intercept (or point-transect) method has been shown to produce more reliable results (Bartelli and De Ment 1970; Mew *et al.* 1980). The method relies on making observations of specified site characteristics at predetermined intervals along transects preferably orientated at right angles to drainage lines and streams.

A similar method has been used for assessing site disturbance following logging in New Zealand (McMahon 1995). A certain number of sampling points is required to ensure a specified error limit on the results. The site disturbance methodology described by McMahon (1995) stipulates a minimum of 400 sample points for an absolute error of 5% and 2500 sample points for an absolute error of 2%, regardless of the area to be surveyed. However, such numbers of observations are impractical for soil mapping or for assessing plantation potential because of the requirement to make time-consuming soil auger borings to a depth of at least 80 cm below the ground surface.

The study of variability in forest soils on the west coast of New Zealand by Mew *et al.* (1980) found that a sampling interval of 40 m along transects 400–600 m apart was reasonably precise (95% confidence limits varying from ± 6% to ± 11%). The intensity of observations made by Mew *et al.* (1980) averaged 22 per 100 ha (one observation per 4.5 ha).

In the Circular Head District, the number and intensity of soil observations depend mainly on the ease of access (whether logged or unlogged) and to a lesser extent on coupe size. Coupe size generally varies from 30 to 100 ha. Sampling intensity is higher in logged coupes where good road access and a network of snig tracks allow relatively rapid progress. The mean sampling intensity for all logged coupes is one observation per 1.9 ha. However, this figure can vary markedly depending on factors affecting access such as the amount of slash. For example, in one logged coupe of 60 ha, 82 sample points were recorded (one observation per 0.7 ha). Conversely, in unlogged and unroaded coupes, sampling intensity is lower because of the difficulty in traversing thickly forested terrain. The unlogged Mawbanna area has a mean sampling intensity of one observation per 3.9 ha.

In both harvested and unlogged coupes, sample points were generally subjectively located along transects at intervals ranging between 50 and 150 m. However, in unlogged coupes, the sampling interval was often varied to coincide with marked changes in vegetation type, topography and drainage pattern. Similarly, in logged coupes, sampling interval was varied according to obvious changes in colour of soil exposed in snig tracks and upturned root boles. The interval between transects is much more variable and depends largely on ease of access and on the amount of sampling that can be completed in a day by two teams working on one coupe. In unlogged forests with poor access, this generally results in two transects per coupe. Sampling in logged coupes often follows a dendritic pattern closely related to the distribution of access roads and snig tracks rather than following straight-line transects.

Results

Procedures for assessing plantation potential

Priority ratings for assessing plantation potential depend largely on the stage of forest

Table 3. Site productivity class in relation to soil depth and drainage for all observation sites.

Site productivity class	Limitations affecting site productivity class				No. of observation sites
	None	Soil depth	Drainage	Soil depth and drainage	
1	224 (16%)	-	-	-	224 (16%)
2	-	95 (7%)	178 (13%)	24 (2%)	297 (22%)
3	-	66 (5%)	388 (28%)	299 (22%)	753 (55%)
4	-	5 (< 1%)	1 (<1%)	99 (7%)	105 (7%)
Totals	**224**	**166**	**567**	**422**	**1379 (100%)**

harvesting. Highest priority is generally given to those coupes where harvesting is complete but plantation suitability is uncertain. Second priority is given to unlogged areas which are roaded and within the current Three Year Plan, whereas areas outside the Three Year Plan that are accessed by road and coupes containing oldgrowth or mixed oldgrowth / regrowth are given lowest priority. Within this priority rating, the focus generally is to select coupes first in areas perceived to be marginal. Areas with known high plantation potential such as those dominated by red soils derived from basalt, or poor sites such as those on buttongrass plains, are not normally investigated further.

Once an area is selected, it is sampled according to the methods outlined above and maps showing results of site suitability are prepared. A decision is then made whether to flag all or part of a coupe for potential plantation, or to confirm native forest regeneration. Coupes in which the majority (about 70% or more) of samples are Site Productivity Classes 1 and / or 2 are considered to have plantation potential, but a lower proportion of these classes may be acceptable depending on various other factors. These include the distribution of good and poor quality sites, area to plant or area remaining to sow, distance to market and proximity to existing plantations.

Analysis of data

To date, the unlogged areas assessed total 1612 ha, with 411 soil observations. Logged areas total 1875 ha, with 968 observations. Analysis of all data in relation to plantation productivity ratings and soil depth and drainage are given in Table 3. The results show that over one-third (38%) of the total soil observations are suitable for planting (Site Productivity Classes 1 and 2), with just under two-thirds (62%) comprising marginal (Site Productivity Class 3) and unsuitable (Site Productivity Class 4) sites. However, the proportion of site productivity classes within each coupe varies markedly. Analysis of the data for individual coupes shows that 20 coupes covering 1243 ha (36% of the total area assessed) are dominated by sites with Productivity Class 1 and / or Class 2 ratings and are therefore considered to be suitable for plantations.

Because the observation interval in both logged and unlogged coupes is random and not fixed, it was not possible to calculate standard errors or 95% confidence limits. However, for unlogged coupes, the intensity of sampling (one observation per 4 ha) is similar to that recorded in an area of complex forest soils (one observation per 4.5 ha) in New Zealand (Mew *et al.* 1980), where the standard error and 95% confidence limits were considered to be acceptable. In logged coupes, the observation density is twice that of unlogged coupes (one observation per 2 ha).

Use of the strategies in other areas

The soil-observation strategies described are highly suitable for use in areas where plantation potential is limited only by soil drainage and/or depth to hardpans or bedrock. These attributes are easily identified using hand augers. However, in areas where poor soil structure and stoniness in subsurface layers may be limiting factors, the use of hand augers is generally unsatisfactory, and more comprehensive site investigations using excavated pits are normally required.

In areas where trafficability, erosion hazard, flood hazard, moisture availability and temperature regime may be limitations in addition to soil depth and drainage, the methodology can readily be adapted to assess plantation suitability by recording appropriate soil and site features. These include slope angle, surface rock cover, soil texture, landform, mean annual rainfall and elevation.

Assessment of soil nutrient availability is dependent on collection of soil samples for chemical analysis or reference to similar soils for which appropriate nutrient data are available. On some sites, specialist advice is required for assessment of landslide hazard.

Summary and conclusions

The soil-observation strategies described allow a methodical and quantitative assessment of plantation potential in forested areas with poor access and where soils are highly variable, and very difficult to stratify and map using conventional free survey techniques. The training and use of local 'non-specialist' staff also allows much greater flexibility and probably results in substantially reduced costs compared to contracting scientific personnel. Because the mean observation density (one observation every 4 ha in unlogged coupes and every 2 ha in logged coupes) compares very favourably with forest soil sampling recorded elsewhere, the results are considered to be reliable and sufficiently precise for making confident decisions on plantation potential. Depending on the distribution of site productivity classes within individual coupes, the methodology can allow stratification and specification of alternative management regimes, such as selective logging or regeneration on lower quality sites and plantation establishment on higher quality sites.

The soil-observation strategies described for Circular Head District can be used successfully in other parts of Tasmania where soil drainage and/or soil depth to hardpans or bedrock are the major limiting factors to plantation suitability. The methodology can also be adapted easily to assess plantation potential in areas where trafficability, moisture availability, temperature regime, and erosion and flood hazards may further limit site suitability.

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Appendix 1. An example of a completed soil-assessment plot sheet.

Planned Coupe : CF 019 A. **Assessed By :** JAC / SJS **Date :** 6 / 7 / 98

PLOT No.	RATING	SOIL PROFILE	VEGETATION TREE	VEGETATION SHR.	VEGETATION GR.	AUGER DIFF.	BWD STOCKING
01	3	G. → 50 | L. G. → 80	0·7.	12.14. 15.	24. 26.	(E) M D	L M H
02	2	Br. → 30 | O. Br → 65 | HP.	0·7.	8·12. 14·15.	24. 26.	E (M) D	L M H
03	2	P 10 | G → 30 | G. O. M. → 50 | O. G. M. → 70 | HP.	0·7.	12.14	24 26.	E (M) D	L M H
04	1.	T.S. 5 | P. Y. → 50 | O. Br. → 80	O.	8·12. 14.	24. 23.26.	E (M) D	L M H
05	2	O. Br. → 50 | HP.	0·7.	10.12. 14.	23. 24·26.	E (M) D	L M H
06	4	P. 5 | L. G → 25 | HP GV.	0·6·7.	10.12.	24. 26.	E M (D)	L M H
07	4	P. 10 | G. S. → 20 | HP. GV.	0·7·6.	14.12. 10.	23. 24·26.	E (M) D	L M H
08	2	L. Br → 50 | O. Br → 70 | HP.	0·7·	10.12. 14·	24. 26.	E (M) D	L M H
09	2	P 5. | D. G. → 40 | P. Br O.M. → 80.	0·6·7.	10·12	24 26	E (M) D	L M H
10	3	P 5 | D. G. → 30 | HP. GV.	0·1·7·6·	12.10. 15.	24. 26.	E M (D)	L (M) H
11	2	G. → 35 | P. Br. → 60 | HP. GV.	0·6·7.	14·12.	24. 26.	E (M) D	L M H
12	1.	L. Br. → 40 | P. Y → 50 | P. Y. O.M. →	0·6·7.	9.14. 12.	24. 26.	E (M) D	L M H
13	2	P. 5. | P. Br → 40 | P. Y. Br. → 70 | HP.	0·6·7.	14·12.	24. 26.	E (M) D	L M H
14	2	Br. 10 | Y. Br. → 70 | HP.	0·6·7.	12.14.	24. 26.	E (M) D	L M H
15	3	G. → 40 | HP GV.	0·6·7.	8.14. 12.	24. 26.	E (M) D	L M H
16	2	P 10 | O. Br → 55 | HP.	0·1·6·7.	12·14·	24. 26.	E (M) D	(L) M H
17	2	Br → 30 | O. Br → 70 | HP.				E M D	L M H

Appendix 2. Codes for soil-assessment plot sheets.

RATING
(Plantation Suitability)

	Depth		Drainage	Native Vegetation
< Class **1** > High Productivity	>80cm	and	Well drained : yellow, brown or red colours below topsoil. or Moderately well drained : grey mottles between topsoil and 30cm overlying yellow, brown or red colours.	E.obliqua with broadleaved understorey (e.g. dogwood musk) but sometimes poorer quality forest and scrub (e.g. Ti-tree, banksia).
< Class **2** > Medium Productivity	50-80cm	and/or	Imperfectly drained : grey colours dominant between topsoil and 30-60cm overlying yellow, brown or red colours with <50% grey mottles.	Eucalypts plus mixed understorey (e.g. Ti-tree, A.mucronata).
< Class **3** > Low Productivity	25-50cm many quartz gravels in upper 60cm	and/or	Imperfectly drained : grey colours dominant between topsoil and >60cm with compact layer (hard pan). or Poorly drained : very dark topsoils and grey colours to >60cm, sub-soils usually very wet (sloppy).	Eucalypts (mainly E.ovata) with mixed understorey (e.g. Ti-tree, A.mucronata, etc.). E.ovata with dense understorey of Ti-tree, paperbark, but sometimes rainforest : manferns and horizontal.
< Class **4** > Very Low Productivity	<25cm	and/or	Poorly to very poorly drained : variable thickness of peat over quartzite or sand/quartzite gravels.	Buttongrass plain.

SOIL PROFILE

Codes : **Y** - Yellow **Br** - Brown **O** - Orange **G** - Grey **L** - Light **D** - Dark **M** - Mottled **W** - Wet
B - Black **Gv** - Gravel **S** - Sand/Silt **P** - Peat **TS** - Topsoil **HP** - Hard Pan **Q** - Quartz.

Depth : Numerical entry in range 5-80cm.

AUGERING DIFFICULTY

Codes : **E** - Easy **M** - Moderate **D** - Difficult.

BLACKWOOD STOCKING

Codes : **L** - Low **M** - Medium **H** - High.

VEGETATION

Tree Species

- \- = nil
- O = E.obliqua
- N = E.nitida
- B = E.brookeriana/E.ovata
- 1 = Blackwood
- 2 = Myrtle
- 3 = Sassafras
- 4 = Celery Top Pine
- 5 = Leatherwood
- 6 = Native Willow
- 7 = Woolly Ti-tree

Shrub Species

- \- = nil
- 8 = Dogwood
- 9 = Paperbark
- 10 = Goldeywood
- 11 = Stinkwood
- 12 = Tallow Wood
- 13 = Lance Wood
- 14 = Prickly Mo
- 15 = Manferns
- 16 = Musk
- 17 = Horizontal
- 18 = Banksia
- 19 = Native Pepper
- 20 = Native Plum
- 21 = Guitar Plant

Ground Species

- \- = nil
- 22 = Baurea
- 23 = Bracken
- 24 = Cutting Grass
- 25 = Button Grass
- 26 = Sword Grass
- 27 = Hard Ferns
- 28 = Wet Ferns