A Methodology for Assessing and Classifying Site Productivity and Land Suitability for Eucalypt Plantations in Tasmania

M.D. Laffan
Forestry Commission, Tasmania

Abstract

A basic framework is described for the assessment and classification of site productivity and land suitability for eucalypt plantations in Tasmania. The classifications are based on assessment of land qualities which can be determined from characteristics measured during land resource surveys.

Four classes of site productivity (high, medium, low and very low) are defined in terms of peak mean annual volume increment (MAI) of forest growth expressed as m^3/ha/yr. The productivity classes and ratings of MAI are intended to provide rankings of site quality which indicate approximate rates of growth only. Correlation of forest growth from measurements of trial plots with relevant land qualities allows assessment of productivity class from land qualities alone. Six land qualities are assessed: temperature regime, moisture availability, drainage, rooting conditions, nutrient availability and nutrient retention. The most limiting land quality determines the productivity class.

Four classes of land suitability are defined, based on guidelines for land evaluation published by the Food and Agriculture Organisation. Class 1 (highly suitable) has no significant limitations for plantation productivity or use, whereas Classes 2, 3 and 4 (moderately suitable, marginally suitable, unsuitable) have significant limitations, or hazards of increasing severity. Classes 2 to 4 are divided into subclasses which indicate the kind of limitation affecting suitability for plantations.

Introduction

A recent financial evaluation of eucalypt plantations in Tasmania (Gerrand *et al.* 1993) stresses the importance of site quality in determining management regime and potential productivity. Gerrand *et al.* (1993) consider that only high quality sites with mean annual volume increment (MAI) greater than 20 m^3/ha/yr are likely to be viable, although pulpwood production may be profitable on medium quality sites (MAI ~15 m^3/ha/yr) that are close to mills and have low establishment and land costs. Although height and species composition of native forests have been used widely to assess site quality, they have not always proved to be reliable indicators of potential plantation growth.

A systematic and objective methodology for assessing and classifying site productivity and overall land suitability for plantations has recently been developed for Tasmanian conditions (Laffan 1993). The methodology is based on assessing various land attributes including climate, soil and topography.

Site productivity (or site quality) is a measure of the relative productive capacity of a site for specified forest species. It is dependent on various soil and climatic factors such as temperature, rainfall, soil depth, drainage conditions and nutrient status. Site index (mean dominant tree height at a specified age) and MAI are the most commonly used measures of forest performance.

Land suitability is defined as the fitness of a given type of land for a specified kind of land use (Food and Agriculture Organisation 1976). It differs from land capability which is the evaluation of land for a range of broadly defined uses generally including agriculture, forestry, recreation and catchment protection. Because land suitability refers to sustainable use, land degradation hazards as well as management limitations and site productivity must be taken into account.

The classifications of site productivity and land suitability outlined here apply to the main commercial eucalypts currently recommended for plantations (*Eucalyptus globulus* and *E. nitens*) although it is recognised that species may vary considerably in survival and growth characteristics at particular sites.

The classifications are based on assessments of land qualities which affect; (a) site productivity and (b) plantation management and land degradation.

Land qualities are those attributes of land which influence its suitability for a specified use. Erosion hazard, moisture availability, tree-rooting conditions and machine trafficability are examples of land qualities relevant to plantation forestry. Land qualities are determined by attributes called land characteristics which can be measured or estimated during soil surveys. Examples are slope angle, soil drainage class, effective soil depth, pH and organic matter content.

The assessment of suitability does not take account of hazards such as forest fire or pests and diseases, nor does it consider in detail the quality of wood production and socio-economic factors.

Classification

Site productivity

Four classes of site productivity are defined in terms of peak MAI expressed as $m^3/ha/yr$. These are:

Productivity Class 1
—high productivity (MAI > 20);

Productivity Class 2
—medium productivity (MAI 15–20);

Productivity Class 3
—low productivity (MAI 10–15);

Productivity Class 4
—very low productivity (MAI < 10).

To classify sites with very high productivity, Class 1 is further subdivided into 1A with high productivity (MAI 20–30) and 1B with very high productivity (MAI > 30).

The ratings of MAI given for each productivity class apply mainly to eucalypts and are less precise for radiata pine. The intention is to produce a ranking of site quality from the very best to the poorest and to indicate approximate rates of growth.

Correlation of forest growth from measurements of trial plots with various land qualities allows assessment of productivity class from land qualities alone.

Land suitability

The classification of land suitability for plantation forestry has been adapted from land evaluation classifications of the Food and Agriculture Organisation (1976, 1984). It is an hierarchical classification comprising four classes of suitability (Table 1).

Class 1 has no significant limitations for plantation productivity or for sustainable use in plantation forestry. Classes 2 to 4 have significant limitations of increasing severity affecting site productivity, management or land degradation hazards. Use of Class 4 land is regarded as prohibitive in terms of very low site productivity, very severe risk of land degradation or high development or management costs.

The land suitability classes are defined in terms of productivity classes, management

Table 1. Land suitability classification for eucalypt plantations.

Class	Designation	Definition
1	Highly suitable	Land having negligible or slight limitations affecting site productivity (Productivity Class 1, peak MAI* > 20), and with negligible or slight management limitations or degradation hazards.
2	Moderately suitable	Land having moderate limitations affecting site productivity (Productivity Class 2, peak MAI 15-20), or land having higher productivity but with moderate management limitations or degradation hazards.
3	Marginally suitable	Land having severe limitations affecting site productivity (Productivity Class 3, peak MAI 10-15), or land having higher productivity but with severe management limitations or degradation hazards.
4	Unsuitable	Land having very severe limitations affecting site productivity (Productivity Class 4, peak MAI < 10), or land having higher productivity but with very severe management limitations or severe to very severe degradation hazards.

* Mean annual volume increment in $m^3/ha/yr$.

limitations and land degradation hazards. Suitability Class 1 must have a Productivity Class of 1, Suitability Class 2 must have a Productivity Class of at least 2, and so on. The severity of site productivity and management limitations, and land degradation hazards ranges from negligible to slight in Suitability Class 1 to very severe in Suitability Class 4. Because some relatively high-producing sites have management or land degradation hazards which restrict their suitability rating, Classes 2 to 4 will include land with potential forest productivity higher than the class limits shown. For example, undulating land having high productivity (MAI > 20 $m^3/ha/yr$) but with a moderate limitation of surface boulders which restricts access by silvicultural machinery, would be rated as land suitability Class 2.

Classes 2 to 4 are divided into subclasses which indicate the kind of limitation affecting management, land degradation or production potential; for example, trafficability, erosion hazard or tree-rooting conditions. These are shown as lower-case letters after the suitability class (for example 2t, 2e, 2r). There are no subclasses to Class 1. Table 2 outlines suitability subclasses in relation to land qualities and land characteristics relevant to plantation forestry. The land qualities are grouped according to those affecting mainly site productivity and those affecting mainly management and land degradation. If found to be relevant, other climatic features such as solar radiation, rainfall distribution and temperature data will eventually be included as land qualities. Soil salinity is not assessed because, apart from estuarine margins, it is likely to be limiting only in areas where mean annual rainfall is less than 800 mm. Such areas are rated as unsuitable on the basis of very low moisture availability. In Table 2, not all land characteristics known to affect the corresponding land quality are listed. For example, climatic effects are often associated with land degradation hazards. However, in this methodology, climate is not considered to be as important as the other land characteristics listed, and consequently it is not used to assess land degradation hazards.

Table 2. Land suitability subclasses for plantations in relation to land qualities and land characteristics.

Suitability subclass	Limiting land quality	Land characteristics which are used to assess the land quality
Qualities affecting site productivity		
p	Temperature regime	Altitude.
m	Moisture availability	Mean annual rainfall, soil-moisture storage based on field texture, soil depth, stoniness, drainage, native vegetation type.
d	Drainage	Soil-drainage class.
r	Rooting conditions	Effective rooting depth, ease of root penetration based on field texture, structure, stone content.
l	Nutrient availability	Total phosphorus (perchloric acid digestion), organic carbon (Walkley and Black 1934).
n	Nutrient retention	Cation exchange capacity (NH_4Cl at pH 7.0), field texture profile, native vegetation type.
Qualities affecting plantation management and land degradation		
t	Trafficability	Slope angle, rock outcrop, surface boulders, drainage.
f	Flood hazard	Landform, soil-profile development.
e	Erosion hazard	Aggregate stability, permeability, drainage, stone content, slope angle, existing erosion.
c	Landslide hazard	Geology, soil properties, slope angle, existing landslides.

Assessment of land qualities

The assessment of land qualities is made for the dominant soils recognised at each potential plantation site, in conjunction with environmental information (mean annual rainfall, landform, slope angle, elevation, geology and native vegetation).

Each of the 10 land qualities outlined in Table 2 is given a range of rating values against which land characteristics for each dominant soil are compared. The ratings are qualitative only and are expressed as a degree of limitation using the terms negligible, slight, moderate, severe and very severe. The most limiting land characteristic determines the rating value. The ratings are based on the principles of land evaluation developed by the Food and Agriculture Organisation (1976, 1984).

Examples of the assessment criteria and ratings are given for rooting conditions (r) and trafficability (t) in Tables 3 and 4. Assessment criteria and ratings for other land qualities are given in Laffan (1993).

Rooting conditions are determined by the effective root depth and ease of root penetration. Effective rooting depth is the maximum depth of soil that can be potentially exploited by tree roots and which can provide a suitable medium for root development, and water and nutrient uptake. It is the depth to a layer which physically impedes root development such as bedrock, cemented or compacted pan, waterlogged horizon, massive and slowly permeable clay, or stony horizon with negligible fine earth (particles < 2 mm). Ease of root penetration is a measure of the suitability of the effective

Table 3. Assessment criteria for rating rooting conditions (r).

Characteristics	Rating* (degree of limitation)			
	Negligible	Moderate	Severe	Very severe
Depth to limiting layer†	> 80 cm	50–80 cm	25–50 cm	< 25 cm
Texture profile and structural development	Uniform sands or loams or gradational soils with well-structured subsoils.	Duplex soils with structured clay subsoils or gradational soils with poorly structured subsoils.	Structured uniform clays or duplex soils with massive clay subsoils.	Massive uniform clays.
Stones in profile‡	< 20%	20–50%	50–90%	> 90%

* The rating is determined by the most limiting characteristic (each characteristic is assessed independently).
† Bedrock, pan, massive clay subsoil, water-table, abundant stones with negligible fine earth.
‡ Stones includes all coarse fragments (gravels, cobbles, stones, boulders).

Table 4. Assessment criteria for rating trafficability (t).

Characteristics	Rating* (degree of limitation)			
	Negligible	Moderate	Severe	Very severe
Slope angle	0–20% (0–12°)	20–30% (12–17°)	na	> 30% (> 17°)
Rock outcrop, surface boulders (% of land surface)	0–10%	10–20%	20–50%	> 50%
Drainage	Rapidly, well-drained, or moderately well-drained	Imperfectly drained	Poorly drained	Very poorly drained

* The rating is determined by the most limiting characteristic (each characteristic is assessed independently).
na = not applicable

root depth as a medium for root development. It is determined by soil field texture, structure and stone content. The implications of management practices such as ripping and mounding on the alleviation of limiting subsoil characteristics are discussed by Laffan (1993).

Two examples of how to use Table 3 are as follows: a deep (> 80 cm) gradational soil with a well-structured subsoil but having 30% stones throughout the profile would be rated as moderate, whereas a duplex soil with surface layers 45 cm thick overlying a massive clay subsoil would be rated as severe for rooting conditions.

Trafficability refers to the ease with which forest machinery such as bulldozers and skidders used for site preparation, forest

Table 5. Assessment of site productivity class and land suitability class from land qualities.

Land qualities (subclass)	Site productivity class/land suitability class*			
	1	2	3	4
Land qualities affecting site productivity				
Temperature regime (p)	negligible	moderate	na	very severe
Moisture availability (m)	negligible–slight	moderate	severe	very severe
Drainage (d)	negligible–slight	moderate	severe	very severe
Rooting conditions (r)	negligible	moderate	severe	very severe
Nutrient availability (l)	negligible–slight	na	severe	na
Nutrient retention (n)	negligible–slight	moderate	severe	na
Land qualities affecting plantation management and land degradation				
Trafficability (t)	negligible	moderate	severe	very severe
Flood hazard (f)	negligible–slight	moderate	na	severe
Erosion hazard (e)	negligible–slight	moderate, moderate to severe	severe	very severe
Landslide hazard (c)	negligible–slight	moderate	na	severe

* The most limiting land quality determines the productivity class (first six land qualities) and the suitability class (all 10 land qualities), and also the suitability subclass notation.
na = not applicable

tending and harvesting can traverse the land. It is also often directly related to land degradation such as compaction caused by inappropriate use of machinery. The main land characteristics affecting trafficability are slope angle, rock outcrop, surface boulders and drainage. Drainage affects mainly the wet-bearing strength of the soil, with poorly and very poorly drained soils having low-bearing strength compared to well-drained and rapidly drained soils. Trafficability problems on poorly drained soils may be minimised if machinery access is avoided when the soils are saturated. Trafficability is also affected by soil texture, with silty soils being more vulnerable to compaction and structural deterioration than clays or sands. The assessment criteria for rating trafficability are outlined in Table 4. For example, a well-drained soil occurring on 12% slopes with 15% surface boulders would be rated as moderate, whereas a very poorly drained soil occurring on 5% slopes with no rock outcrop or surface boulders would be rated as very severe for trafficability.

Assessment of site productivity class and land suitability class from land qualities

For each soil, productivity class and suitability class are determined by comparing land qualities with plantation requirements in an overall rating table (Table 5). The most limiting land quality determines the productivity class (using the first six land qualities in Table 5) and overall suitability class along with the subclass notation (using all 10 land qualities in Table 5).

Productivity Class 1 is divided into 1A and 1B depending on MAI values. The higher growth

rates in Class 1B (MAI > 30 m^3/ha/yr) relate to negligible limitations for all land qualities. Land Suitability Classes 2–4 are divided into subclasses designated by the most limiting land quality. Depending on the number of limiting land qualities, more than one subclass may be shown after the suitability class, for example 3 mle. Productivity classes are not divided into subclasses based on limiting land qualities. A soil which has the following ratings for land qualities: negligible for temperature regime (p), drainage (d), nutrient availability (l) and nutrient retention (n), slight for moisture availability (m), moderate for rooting conditions (r), very severe for trafficability (t), negligible for flood hazard (f), moderate for erosion hazard (e) and landslide hazard (c), is assessed as Productivity Class 2, Suitability Class 4 t. A highly productive soil (MAI 20–30 m^3/ha/yr) but with 15% surface boulders which restrict trafficability is classified as Productivity Class 1A, Suitability Class 2 t. A soil with low productivity because of low moisture availability and with severe erosion hazard is classified as Productivity Class 3, Suitability Class 3 me.

Soils for which reliable plantation productivity data (MAI) are available are classified initially according to Table 1, and then assessed for land qualities to check the suitability class and determine the subclass. In north-eastern Tasmania, a range of widely varying soils for which reliable forest growth data are available showed very good correlation between productivity class determined from peak MAI and that assessed from land qualities alone. As further information becomes available on the relationship between land qualities and forest productivity and hazards, the ratings for land qualities and suitability classes will be modified accordingly.

A flow chart for assessing highly productive and suitable land for plantations is given in Laffan *et al.* (1994).

Acknowledgements

Bill Neilsen, Forestry Commission, Tasmania, and Adam Gerrand and John Grant, Intensive Forest Management (IFM) program, are particularly thanked for significant contributions during development of the methodology. Numerous others are thanked for making useful comments and suggestions during earlier versions of this paper. The paper was completed whilst the author was seconded to the Forests and Forest Industry Council and the Council's support is acknowledged.

References

Food and Agriculture Organisation (1976). *A Framework for Land Evaluation.* FAO Soils Bulletin 23. Soil Resources Development and Conservation Service, Land and Water Development Division, FAO, Rome.

Food and Agriculture Organisation (1984). *Land Evaluation for Forestry.* FAO Forestry Paper 48. FAO, Rome.

Gerrand, A., Prydon, R. and Fenn, G. (1993). A financial evaluation of eucalypt plantations in Tasmania. *Tasforests* 5: 77–97.

Laffan, M.D. (1993). *Site Productivity and Land Suitability for Eucalypt and Radiata Pine Plantations in Tasmanian State Forest: A Framework for Classification and Assessment of Land Resources.* Soils Technical Report No. 3. Forestry Commission, Tasmania.

Laffan, M., Grant, J. and Hill, R. (1994). How to select highly productive and suitable land for plantations in Tasmania using soil and site properties. In: *Faces of Farm Forestry*, pp. 95-100. Proceedings of the Australian Forest Growers Conference, 2–5 May, Launceston.

Walkley, A. and Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science* 37: 29–38.