Soil mapping in Tasmania's State forest

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Abstract

A five-year project commenced in 1990 to characterise and map soils on State forest in Tasmania, with special reference to sustainable forest management and site suitability for plantations. An appropriate computer database and a system for recording soil and site information in the field were developed early in the project. Standard laboratory methodology, including physical and chemical analysis, was established. An improved method for assessing soil erodibility, and a classification of site suitability for plantations based on land resource information were also developed.

Mapping of three 1:100 000 sheets: Pipers, Forester and Forth, *was completed by the end of the project. These maps cover approximately 154 000 ha of State forest and include the major centres of existing plantations on public land in the north of the State. Explanatory reports provide details of soil properties, environmental features and potential degradation hazards, and prescribe management practices for the sustainable use of native forests and plantations. The unit cost of the mapping ($3.50/ha) is very low compared to the outlay (> $800/ha) typically required for the establishment of plantations. Soil surveys were also carried out on 80 discrete areas (a total of 6500 ha) throughout the State to determine their suitability for plantation development. A handbook characterising a range of common forest soils from around Tasmania, together with management recommendations, was completed as part of the project. The results of the project have been widely disseminated and they apply to all multiple-use forests in Tasmania.*

Introduction

All Tasmanian forest soils must be managed according to their capability. The sustainability of multiple-use forests depends on the implementation of the sound forest practices encompassed in the Tasmanian *Forest Practices Code* (Forestry Commission 1993). The Code is based predominantly on proper management and care of soils and related factors.

The benefits of having detailed soil-survey information depend largely on the intensity of future development. The expenditure on any intensive plantation or regeneration development is such that the cost of soil surveys is a minor but vital part.

The value of soil-survey information lies in:

- Allowing planning of necessary soil treatment and avoidance of unnecessary operations, resulting in cost-effective establishment of intensive forest developments;
- Providing information for predicting site productivity for both native forests and plantations;
- Detailed soils information being available so that environmental problems can be anticipated and minimised, and forest practices objectives met; and
- The monitoring of soil changes to ensure sustainable practices are used.

With the increasing importance and emphasis on plantations, and the resultant high investment costs involved, appropriate site and soil-specific management procedures are needed.

Previous soil surveys carried out in Tasmania have not considered forest soils or forest uses in detail (Grant *et al.* 1995c). There has been scant soils information available on which Forest Practices Officers can base their management decisions, with reference to operational problems, site productivity and difficulties encountered during and after logging. Tasmanian soils need to be classified according to productivity, capability for forest operations and hazard rating (Brown and Laffan 1993; Laffan 1993).

A detailed mapping project was initiated in June 1990 to provide soils information relevant to forest management. Funding for a period of five years was provided by the National Landcare Program (NLP) and the Intensive Forest Management (IFM) Program of the Tasmanian Forests and Forest Industry Council, with support from Forestry Tasmania. The mapping was concentrated on State forest in northern Tasmania. To provide suitable forest management information in areas not covered by detailed soil maps, a handbook was produced covering a range of forest soils from around the State.

Soil mapping

Mapping is the most efficient way to collect soils data over large areas because it allows the characterisation, assessment, analysis and spatial distribution of the soils to proceed in a coherent and logical manner. Soils and their relationship to each other and to the environment are best recognised when they are considered over a relatively wide area and it is these relationships that are a major aid to the mapping and the understanding of the soils. The information gathered may be used to target areas of forest for a number of purposes while providing baseline soils information in a format compatible at a national level. Mapping provides information to aid in the selection of appropriate management practices and can provide derived maps which define such hazards as erodibility and landslip potential (Gunn *et al.* 1988; Grant *et al.* 1995c).

Soil maps form a more solid basis for future intensive collection and analysis of soil information than scattered, 'ad hoc' surveys or site-specific inspections. Small-area, large-scale plantation suitability/soil surveys can be important when information is required immediately, and they provide an appropriate short-term decision aid. The result is usually a report and map showing suitability for plantations rather than a soil map, and the costs are generally higher (Grant *et al.* 1995a).

Soil development is determined by environmental factors operating on soil parent material over time. It should be possible to predict some soil characteristics and patterns by modelling parameters such as wetness indices within defined geological rock types. Attempts undertaken as part of this project produced poor results and indicated that greater topographic detail, with at least 10 m contours, would be needed to adequately define micro-sites (Grant *et al.* 1994). If models can be produced that predict soil distribution from known information, they could reduce the cost of soil surveys and could provide greater detail of soil complexes. However, such models might only be useful where detailed geology maps exist and where geology relates closely to soil parent material.

Factors relating to the fertility of Tasmanian forest soils

The productivity capacity of Tasmanian forest soils relates to their chemical and physical fertility. Chemical fertility relates to the presence or absence of plant nutrients in the soil and their accessibility by plants. Physical fertility is closely tied to soil depth, stone content, texture, structure and strength, which affect aeration, water supply and root penetration.

Soil organic matter (humus) is important in providing and storing nutrients and a measure of the quantity of soil organic matter present provides one useful index of fertility (Table 1). Soil organic matter also has a role in improving soil structure and holding water. Soil nitrogen (N) is largely held in

Table 1. Ratings for chemical and physical laboratory analyses.

Rating	Organic carbon (%)	Total phosphorus (ppm)	Total nitrogen (%)
Very high	> 10	-	-
High	5–10	> 250	> 0.6
Medium	2–5	100–250	0.3–0.6
Low	< 2	< 100	< 0.3

the organic matter and therefore levels of nitrogen and organic matter are closely allied in Tasmanian forest soils (Davis *et al.* 1983). Levels of phosphorus (P) are low in many Australian soils and this nutrient is the most limiting one in many Tasmanian soils. Various techniques can be used to estimate the amount of phosphate in the soil that is available to plants. However, total P, following perchloric acid digestion (Olsen and Sommers 1976), has been found to be more easily interpreted as an indicator of the P nutrition status of Tasmanian forest soils than measures of available P (Neilsen and Crane 1977) (Table 1).

Many nutrients besides nitrogen and phosphorus are essential for plant growth and low levels of supply of potassium, calcium and magnesium have been determined for some Tasmanian forest soils.

Productivity

Investigations of productivity on a wide variety of eucalypt plantation sites indicated that stand growth was correlated with a number of soil physical and chemical factors and also site factors such as rainfall and altitude. Relationships of growth with various combinations of factors varied with soil parent material and, while some overall correlations were good, exceptions to general rules were common (Gerrand 1991a).

Improved relationships were discerned within specified groups of soil parent material but indications were that many factors needed to be considered in assigning productivity and that factors limiting growth could vary from soil to soil (Davis *et al.* 1983; Gerrand 1991b). For greater accuracy in predicting productivity, all factors need to be considered together in conjunction with soil properties.

A method for assessing productivity was developed during the mapping project, based on a set of topographic, climatic and soil variables (Laffan 1993). These include altitude, landform, mean annual rainfall, soil drainage, soil depth, texture, stoniness and nutrient status. It is a limiting factor system where the most limiting attribute(s) determines the overall rating for site productivity. To incorporate recent growth data for a range of eucalypt stands in Tasmania (Osler *et al.* 1996), some of the assessment criteria have been revised (Laffan 1997).

Land evaluation for forestry

Land evaluation systems such as land suitability and land capability are generally used to assess the potential of land for alternative kinds of use or its suitability for a specified use. They incorporate soils information and a wide range of other variables such as topography, climate and degradation hazards into the classification. They allow assessment of the appropriate use of land by determining its capacity for supporting various management regimes and its fitness for each of those regimes.

Land suitability is defined as the fitness of a given type of land for a specified land use. 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.

Soil and site information are used to classify land according to its productivity for both native and plantation forests and suitability for plantation forestry. Land suitability for plantations takes into account land

Table 2. Areas (ha) of productivity classes in relation to slope for State forest in northern Tasmania. (MAI = mean annual increment.)

Productivity class	Expected MAI (m^3/ha/yr)	Map sheet *Pipers*	Map sheet *Forester*	Map sheet *Forth*	**Total (ha)**
Slope < 30%					
1	> 20	10 691	34 281	11 318	**56 290**
2	15–20	0	385	636	**1 021**
3	10–15	19 045	9 812	6 792	**35 649**
4	< 10	5 813	5 895	1 917	**13 625**
Sub-total		35 549	50 373	20 663	**106 585**
Slope > 30%					
1	> 20	7 017	20 482	10 538	**38 037**
2	15–20	0	0	0	**0**
3	10–15	710	1 506	1 772	**3 988**
4	< 10	821	0	4 298	**5 119**
Sub-total		8 548	21 988	16 608	**47 144**
Total (ha)		**44 097**	**72 361**	**37 271**	**153 729**

degradation hazards (erosion, landslides, flooding) and trafficability, as well as site productivity. For classifying forest soils in Tasmania, four productivity and four suitability classes have been defined (Laffan 1993; Laffan 1994; Laffan *et al.* 1994). Productivity is defined in terms of peak mean annual volume increment (MAI) expressed as m^3/ha/yr. Productivity Class 1 has high site productivity with MAI > 20 m^3/ha/yr whereas Productivity Class 4 has very low site productivity, with MAI < 10 m^3/ha/yr (Table 2). Suitability Class 1 (highly suitable) is highly productive and has no significant trafficability limitations or degradation hazards. Suitability Classes 2, 3 and 4 (moderately suitable, marginally suitable, unsuitable) have significant limitations of increasing severity affecting site productivity and/or trafficability and/or degradation hazards.

Soil surveys of forest areas in Tasmania

Initial requirements for the mapping and storage of data were the development of a system for recording soil and site characteristics in the field (McDonald *et al.* 1990; Laffan and Grant 1992) and an appropriate computer database (Grant and Laffan 1991). This proceeded in conjunction with the mapping of the first sheet. Sampling of the soils and subsequent analysis highlighted the need for a standard methodology in the laboratory. This was established early in the project (Herbert 1992) and has been revised to include improved methods (Herbert *et al.* 1994).

The erodibility rating of soils is an important part of the *Forest Practices Code* (Forestry Commission 1993), particularly in relation to management prescriptions for protecting soil values. To facilitate the classification of soil erodibility, a semi-quantitative methodology was developed, based on both field and laboratory determinations of soil properties (Laffan *et al.* 1996a).

Soil mapping of State forest was carried out at scales of 1:50 000 and 1:100 000, utilising aerial photography, field checking and existing soil and geology information. As the mapping progressed, the soil observations were compiled into soil profile classes and entered onto a database created on INFORMATION on the Forestry Tasmania computer system. The soil profile class is a grouping of soils derived from similar parent material that has relatively uniform properties and a relatively uniform sequence of horizons. For ease of identification, each soil profile class is given a local geographic name (e.g. Sideling soil profile class) and is tabulated in the reports according to geology, landform, drainage class, parent material and native vegetation type.

During the project, 200 full profile descriptions were recorded, covering 75 different soil profile classes, and 45 profiles were sampled for physical and chemical analyses. Thirteen sampled profiles were also analysed for clay mineralogy.

Soil map units are composed of soil profile classes and they are delineated by boundaries which have been digitised onto the ARC/INFO Geographic Information System (GIS). Because of the scale of mapping and highly variable environmental features, the soil map units include more than one soil profile class. A range of map units including soil associations, complexes, undifferentiated groups and miscellaneous units (Gunn *et al.* 1988) has been used to account for the complex array of soils encountered.

Mapping of three sheets (*Pipers*, *Forester* and *Forth* from the Tasmania 1:100 000 Topographic Map Series, Lands Department) was finished by the end of the five-year project (Laffan *et al.* 1995a; Grant *et al.* 1995a; Hill *et al.* 1995). These maps cover approximately 154 000 ha and include the main centres of existing plantations on public land in the north of the State.

Site information and physical and chemical soil characteristics enabled the identified soils to be classed according to plantation productivity, suitability, management constraints (e.g. nutrient availability, drainage, trafficability) and land degradation hazard (e.g. erodibility, landslide hazard). Maps of any of these land qualities can be derived easily and produced from the GIS. For planners and forest managers, such maps are more useful than basic soil data as they provide interpretive information which is directly applicable to forest management.

Output from the project consists of 1:50 000 scale GIS and dyeline maps for each of the three mapped sheets of:

- Soil map units;
- Site productivity;
- Site suitability for plantations;
- Soil erodibility; and
- Soil susceptibility to mixing.

Of 153 729 ha mapped, 61% was Productivity Class 1, and 37% was Class 1 land on easy topography (slopes < 30%) suitable for intensive development (Table 2). Very little of the area mapped was Productivity Class 2, a result of the steep gradients in rainfall and altitude in Tasmania. The majority (81%) of the steep country was Productivity Class 1, a result of this country generally being in higher rainfall zones with deep, fertile soils. On slopes of < 30%, Productivity Class 3 comprised 23% of the area, with *Pipers* map sheet having the greatest proportion of this land. Conversely, *Pipers* had the lowest proportion of Productivity Class 1 land (Table 2).

Results from soil surveys have been used to relate the Tasmanian *Forest Practices Code* to specific soil types in Tasmania to replace the geology previously used in lieu of soils (Forestry Commission 1993).

Handbook of Tasmanian forest soils

The major objective of the soils handbook, produced as part of the project, was to provide forest managers with basic information on Tasmanian forest soils, including identification, profile features and management requirements of the soils. The book is aimed especially at forest managers with responsibility for areas without detailed soil maps and reports. The book describes 34 soils commonly found in Tasmania's multiple-use forest (Grant *et al.* 1995c). The soils are keyed out on the basis of geology, soil profile features (texture, colour, mottling and pans) and native vegetation type. To facilitate identification of the soils, the book includes colour photographs of typical profiles and native vegetation. Each soil has been interpreted for potential degradation hazards, site productivity and suitability for plantations, and is given recommendations for management.

The handbook also provides background information on soil formation, soil properties, mapping, classification and soil management. More detailed information is appended, including expanded profile descriptions, analytical data, approximate distribution, soil classification, and interpretative data for assessing site productivity and suitability for plantations.

Reconnaissance soil mapping for determining site suitability for eucalypt plantations on specific areas

As part of the IFM project, soil reconnaissance investigations of State forest compartments proposed for eucalypt plantations were commenced in 1992. The objective was to characterise the soils and indicate their distribution, and to assess site suitability for plantations together with recommendations for site preparation prior to planting. Plantation establishment was recommended only for compartments with high site suitability (Suitability Class 1). Eighty separate areas (6500 ha) from throughout the State were inspected.

Cost of forest soil mapping

The cost of soil surveys varies depending on available information, the scale of mapping, the complexity of landforms and soil patterns, and access. For the Tasmanian survey, access to many areas was difficult and the soils could often only be mapped as complex units even where the intensity of observations was high. Detailed geology maps, forest-type photo-interpretation maps and good quality aerial photos were valuable for stratification of survey areas.

The area covered by the soil surveys was 154 000 ha and the total cost of the mapping was $534 000, a cost of $3.50/ha, or $9.50/ha for areas identified as being suitable for intensive plantation development. The cost of $3.50/ha is small compared to the cost of plantation establishment ($800–$1200/ha) or the even greater costs of failed or poorly performing plantations.

In comparison, the cost of reconnaissance or opportunistic surveys of selected sites for specific purposes was approximately $40/ha Such surveys are useful but are often unable to be carried out in time to provide information for forward planning. A sample of approximately one-quarter of these surveys (a total of 1600 ha) revealed that, of the area surveyed, 48% was Suitability Class 1, 26% Class 2, 18% Class 3 and 8% Class 4. Without broad-scale mapping to highlight areas of high plantation potential, the large-scale, high-cost surveys are conducted inefficiently, with less than 50% of the areas surveyed being suitable for plantations.

The *Pipers*, *Forester* and *Forth* map sheets cover a wide range of soils and include most of the geology types found in Tasmania. They thus form a solid basis for further mapping. Future costs should be lower than in this project.

Dissemination of results

Results of the project have been widely disseminated by various methods, including seminars, conferences, written materials and field days. Written materials include articles in Australian and New Zealand soils newsletters (Grant *et al.* 1995d; Laffan 1991, 1992, 1995; Laffan *et al.* 1995b); conference proceedings (Grant and Laffan 1991; Laffan *et al.* 1994; Hill *et al.* 1994; Laffan *et al.*1996b;

Cotching and Laffan 1996); and technical reports, bulletins, handbooks and papers in journals.

As well as presentations at conferences, numerous talks and seminars have been given both intra- and inter-State to explain various aspects of the project. Lectures have also been presented to forest trainees and supervisors, and at training courses for Forest Practices Officers, together with brief field trips. In order to provide practical instruction on the identification and properties of soils and their management requirements for forestry, a series of field days has been held in various Districts throughout the State. It is envisaged that dissemination of results from the soils project will be an on-going process.

Conclusions

The project has produced comprehensive soils information suitable for the sustainable management and use of Tasmania's forests, including those on private as well as public land. Spatial data showing the distribution of soils and interpreted characteristics such as soil erodibility and site productivity for plantations are essential for proper forest planning. This information is best derived from a conventional soil-mapping programme rather than reconnaissance or opportunistic investigations. Soil mapping is very cost-effective when compared to the large financial outlay required for intensive forest management, such as plantation establishment. Further soil characterisation and mapping, particularly in north-western and southern Tasmania, would allow the production of spatial data for areas with high potential for further intensive forest management.

Acknowledgements

The authors acknowledge the contribution of John Grant, Reece Hill, Darren Kidd and Andrew Herbert, who worked on the project. The project was jointly funded by the National Landcare Program, the Intensive Forest Management Program and Forestry Tasmania.

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