SOILS INFORMATION — A BASIC REQUIREMENT FOR EXOTIC FOREST PLANNING

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ABSTRACT

In the early periods of great expansion, exotic forests were planted mainly on soils considered of little value for agriculture. In periods of later expansion or projected expansion, methods of assessing the soil data base for exotic forest growth have become more comprehensive. This field is an evolving one, and a number of experimental approaches are described. Both conventional methods of soil data presentation (soil maps, reports, bulletins) and interpretative methods (maps, sieve overlays, tables, cross-sections) are outlined. A five-point plan is put forward for improving means of providing soils information for, and incorporating it into, the planning for the future of exotic forestry.

INTRODUCTION

The history of exotic forest planting in New Zealand, and indeed in many parts of the world, has been to use soils which have traditionally been considered less suited to agricultural production. Major plantings on the central North Island yellow-brown pumice soils from 1925 to 1935 were made before cobalt additions were found to cure stock sickness (Poole, 1968). Other plantings occurred on areas that, because of steepness, erosion, or infestation by noxious weeds such as gorse, were considered more suited to growing trees than grass or other crops. There has also been considerable planting on coastal sand-dune country primarily for erosion control. Some of these areas are now becoming productive.

The expansion of exotic forest-based industry to increase exports has led to a need to find more land for planting (Bunn, 1979). Fortunately, in the course of this expansion, the soils data base for resource inventory assessment has also developed to a considerable extent (Leamy, 1979). The objectives of this paper are to outline the nature of the soils data base, to trace the

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history of the use of soils information in exotic forest planning, and to show how soils information can be developed to help planning for the future. Increasing sophistication in the use of computers for tree growth modelling studies and the necessity for more accurate predictive power for inputs of energy to overcome site limitations mean that more advanced and detailed techniques must be applied in the provision of basic data.

TYPES OF SOILS INFORMATION AVAILABLE FOR EXOTIC FOREST PLANNING

Soil Physical Data

Soil physical data include morphological descriptive material for soil mapping and taxonomic units based on standardised methods of description (Taylor and Pohlen, 1970; FAO, 1974). The data may also include results relevant to exotic forestry from particle size distribution analyses, dry bulk density measurements, porosity measurements aand available moisture estimates. Penetration resistance and measures of plasticity have been quoted for a number of reference soils (N.Z. Soil Bureau, 1968; Vortman, 1980).

Soil Nutrient Data

Soil samples chosen as representative of all major soil taxonomic units are chemically analysed. Many analytical methods have evolved with relevance to the growth of agricultural crops but are, in certain instances, relevant to tree growth. Selected analyses related to exotic forest growth have been developed in New Zealand (for example, Adams, 1973; Ballard, 1974), and these are carried out specifically for forestry purposes.

Soil Maps and Reports

Basic soil maps show the distribution of soil mapping units which contain a preponderance of the named soil taxonomic units described in bulletins, reports and/or extended legends. The maps are published at various scales, from the total country-wide coverage at the general scale of 1:253 440 to limited coverage at the very detailed scale of 1:2000. An intermediate scale relatively widely used in exotic forest planning is 1:50 000 (or the near equivalent of 1:63 360). Examples are discussed below. Although at first sight soil maps alone do not appear to show much information directly relevant for forestry, they incorporate features which are of considerable value. For example, compound slope classes are distinguished on the basis of a hatching system; slopes $\geqslant 30°$ are shown by vertical hatching; those between 12° and 29° are shown by inclined hatching, and those of $< 12°$ by no line symbol. Rolling phases of mapping units (soils on slopes of 5–12°) may be distinguished on soil map legends in special circumstances.

Maps published in recent years include both physiographic and pedological legends. The physiographic legend conveys general information on drainage classes as well as positions of soils in the landscape. However, in all instances more information is contained in reports than can be shown on the map face and both should be considered in conjunction.

Reports that accompany soil maps vary in content and amount of detailed information they contain. All contain basic descriptions of mapped soils, in some instances (mainly bulletins) with photographs illustrating the soils. Soil Survey reports tend to include briefer descriptions, in abbreviated form such as on extended legends or soil unit summary sheets. Interpretative work for land uses such as exotic forestry is discussed below.

Interpretative Maps and Tables

While it is considered essential to quote basic data on which interpretations are made and from which conclusions are drawn, it is the interpretations which are generally of greatest value to the user. Several methods have been tried by Soil Bureau and others for conveying information relevant to exotic forest planning.

Interpretative Maps

An example of such a map used for direct forestry interpretation only is the 1:63 360 Soil Map of the Inangahua Depression, South Island, showing Soil Limitation Classes for Exotic Forest Growth (Adams *et al.*, 1975). Five classes are derived from tables in the text of the accompanying Soil Survey report (Mew *et al.*, 1975), and are based on combined physical and chemical limitation scores for the various soils identified in the region.

Transparent map overlays at 1:63 360 overprinted with dot and line patterns showing 5 classes of Physical Suitability of Land Use for Exotic Forestry were produced in the course of the King Country land-use study (Department of Lands and Survey, 1978). Many organisations, including DSIR, NZFS, FRI and MWD contributed to this major multi-disciplinary study.

Maps on which suitability for radiata pine was linked with suitability for maize, sugar/fodder beet, and lucerne in terms of numbers of hectares suitable for production were drafted to accompany a report on the potential production of biomass (Leamy and Markham, 1979). These maps showed regions, with histograms indicating hectares suitable for the various crops also on the map face. Explanations of the suitability classes used were given in the accompanying text.

Other maps which may be deemed to be interpretative are those within the Land Resource Inventory Worksheet series produced on a national basis at 1:63 360 by Water and Soil Division, Ministry of Works and Development. These maps carry code symbols which indicate a land-use capability classification for each mapped unit (Ministry of Works and Development, 1979). This classification is not, however, specific to exotic forestry, but seeks to compare suitability ratings for cropping, pastoral, production forestry and general suitability. The system as a whole is described in a *Land Use Capability Survey Handbook* (Soil Conservation and Rivers Control Council, 1971). At present no site indices for *Pinus radiata* are included with these worksheets, but progress is being made with accumulating data on production for future use.

The capability classes are based on landform, soil, geological, climatic and other information derived by a combination of study from available maps, documents and air photographs, and rapid field checking.

Interpretative Tables

Interpretative tables vary in form and in the amount of information they contain.

In the extended legend which formed the major part of the General Survey of the Soils of North Island, New Zealand (N.Z. Soil Bureau, 1954), the soils and land-use section of the tables merely showed that certain soils were "adapted to" forestry, without specifying reasons. Reasons could be deduced from accompanying information on profiles, topography, rainfall and soil erosion assessment. An advance was made in the South Island general survey bulletin (N.Z. Soil Bureau, 1968), where exotic forestry was listed as one of five potential forestry uses and the expected site index on the soil set in question, based on three growth classes for radiata pine, was given. A table was also presented (on p. 162) specifying other exotic trees suitable for planting in the South Island on particular sites. However, once again no direct link was established between the soil factors and the interpretative rating. Such a link was first made by Cutler (1967) in the National Resources Survey, Part V — Otago Region.

Cutler drew up five Soil Forest Classes, some of which had subclasses, linking topography with degree of limitations (*e.g.*, drainage, subsoil pans, texture, nutrients, and from slight through to severe). Although attempts have been made to extend this system on a national basis (Heine, 1975), soil limitations other than those specified by Cutler occur in different parts of the country and no all-embracing system has yet been evolved.

Mew (1980) has attempted a more objective evaluation of soil physical and nutrient limitations for exotic forestry on the West Coast of the South Island, following interim work by Adams and Mew (1976a) and the published work quoted under "Interpretative Maps" above (Mew *et al.*, 1975). In the tables given in the later reports (Mew, 1980) part of which are reproduced here (Table 1), broad basic limitation classes are established and actual limiting factors (defined in more detail in the accompanying text) are shown, together with a degree of limitation, for each soil. The highest degree of limitation for a particular soil for any one factor governs which of the six limitation classes the soil is finally assigned to. Classes are as follows:

Class A — soils with negligible limitations
Class B — soils with slight limitations
Class C — soils with slight to moderate limitations
Class D — soils with moderate limitations
Class E — soils with moderate to severe limitations
Class F — soils with severe limitations

The more general forms of available soils information for exotic forest planning have been outlined above. In the following section, the history of increasing use of soils data in the course of evaluating exotic forestry projects will be traced.

HISTORY OF USE OF SOILS INFORMATION IN EXOTIC FOREST PLANNING

Interest in soils and the effects they could have or might be having on exotic forest growth (and vice versa) was publicised by the production of the bulletin "Soils, Forestry and Agriculture of the Northern Part, Kaingaroa State Forest and the Galatea Basin" (Vucetich *et al.*, 1960). Not only were the soils and their

TABLE 1: SOIL PHYSICAL LIMITATIONS FOR EXOTIC FOREST GROWTH IN THE GREY VALLEY

Arranged within classes in order of physiographic legend. The term "hilly" includes moderately steep and moderately steep to steep slopes as defined by Taylor and Pohlen (1970)

Key: *Limiting Factors*

f = flooding
w.t. = high water-table or soil drainage restriction
p = iron pan in soil or underlying gravels
r = higher rainfall than average
sh = shallow profiles
st = stones or boulders
u.r. = relatively impenetrable underlying rock

Degree of Limitations for each Limiting Factor

0 = negligible
1 = slight
2 = slight to moderate
3 = moderate
4 = moderate to severe
5 = severe

N.B.: NO GREY VALLEY SOILS FALL WITHIN
CLASS A, Soils with negligible physical soil limitations or
CLASS B, Soils with slight physical limitations

Class	*Soils*	*Physiographic Position*	*Limiting Factors*				
			Textural Limitation	*Tangible Impediments to Rooting*	*Lack of Moisture*	*Excessive Moisture*	*Erosion Hazard*
C Soils with slight to moderate soil physical limitations	Ikamatua	Main Post-glac. river terraces	0	2 (sh) 1 (st)	1	0	0
	Arahura	Inter. and high glac. outwash terraces	0	1 (sh) 2 (st)	0	0	0
	Deadman hill	Hilly slopes	0	2 (st)	0	0	1
	Blackball hill	Hilly slopes	0	1 (sh) 2 (st)	0	0	1
	Arahura hill	Hilly slopes	0	1 (sh) 2 (st)	0	0	1
	Soldiers hill	Hilly slopes	0	2 (st)	0	0	1
	Hinau hill	Hilly slopes	0	1 (st) 1 (u.r.)	0	0	2

problems described and mapped in this bulletin, but studies of soil changes induced by land use, possible effects of podzolisation under *Pinus radiata,* and tree growth in relation to soils were also all reported.

Another significant early study was that of Ward and Hocking (1956) for the Te Wera State Forest in Taranaki. This was probably the first time in New Zealand that a soil survey was undertaken specifically to assist in the siting of individual species within an exotic forest.

Will, in a 1970 presidential address to the N.Z. Society of Soil Science (published under Will, 1972), drew attention to the stabilisation measures being set up by planting exotic forests on extensive eroded areas on the East Coast, North Island. While in some ways this is more a geological problem than a soils one, the maintenance of a soil and vegetation cover is of vital importance in watershed management. Subsequent studies (Gage and Black, 1979) have considered slope stability under forest in Mangatu State Forest. Will (1972) also pointed out the need for closer ties between foresters and soil scientists; many of his suggestions have been subsequently adopted.

In 1971 a white paper on Utilisation of South Island Beech Forests was presented to the House of Representatives by the Director-General of Forests. Requests for soils information on the beech project areas were subsequently made to Soil Bureau, DSIR, and resulted in the production of soil maps (at 1:63 360 and, latterly, 1:50 000) and reports covering approximately 4000 km^2 of the West Coast. Smaller areas were surveyed in Nelson and Southland. Results were summarised and presented at a major seminar on the future of West Coast forestry and forest industries held at Hokitika in June-July 1977. Prior to this a series of published and interim reports on the soils in subregions of the West Coast where exotic forestry use was proposed had been made available (Mew *et al.,* 1975; Adams and Mew, 1976a, b). Two other reports on northern and northwestern parts of the project area (Laffan and Adams 1977, and Heine *et al.,* 1977) became available shortly afterwards. All these reports contained interpretative tables setting out specific soil physical and nutrient limitations for exotic forestry as described above. The Inangahua Depression report (Mew *et al.,* 1975) also contained an interpretative map.

The main pedological trends evident from the widespread West Coast survey work, and their relevance to forest use, were brought together in a paper by Mew and Leamy (1977). These authors indicated that hill country and steepland soils with gleying should be regarded with caution in exotic forest productivity projections, and that the findings regarding erosion already made by FRI personnel on limited areas could be extrapolated much further as a result of the soil mapping. Very limited trial work by NZFS and FRI (at that time) meant that few site index predictions could be made on the basis of existing growth plots.

During 1976 the King Country land-use study commenced. This was an interdepartmental study, co-ordinated by the Department of Lands and Survey, begun as land-use conflicts were developing in the region. The study area was slightly larger than the West Coast beech project area, at approximately 4 400 km^2.

While a basic soil survey at 1:63 360 was carried out over the entire area, the approach to data evaluation for exotic forestry and presentation of results differed significantly from those methods used on the West Coast in the following ways:

(1) The entire soil survey was summarised in 17 pages as part of all the technical reports (Department of Lands and Survey, 1978), with a further 12 pages of appendix listing soil properties, and predicted site index. Because of the abbreviated nature of the report, much of the base data and quantitative explanation of limitation terms were omitted.

(2) Map overlays were produced showing, for example, physical suitability of land use for exotic forestry. (Such maps are described in more detail under "Interpretative Maps and Tables".) Soil maps were the main data base.

(3) Site index predictions for *Pinus radiata* were made on the basis of a new FRI technique described by Jackson *et al.* (1977). Actual trial sites were limited over the survey area, but plots of 0.05 ha were established in *P. radiata* stands on as many soils as possible. These stands included shelterbelts and farm forestry areas identified in the course of the soil survey, and for which such parameters as effective soil depth, soil fertility and mean annual precipitation were measured or estimated.

(4) Soils were grouped in the text and on map overlays in terms of suitability (high, medium, low or unsuitable) for exotic afforestation, while limitations were generally placed under a "Comments" heading.

Within the last three years, several experimental approaches to refining soils information for exotic forest planning purposes have been made. These may be grouped under several headings:

Improvement of part of data base in trial work

The permanent sample plot system of FRI has been rigorously studied in the North Island and, as a result of initial screening, detailed work of soil description, analyses, foliage analyses and site factor recording carried out on 360 plots (out of an original total of 6000). This work results from a joint approach by FRI and Soil Bureau, the first stage of which has been reported by Hunter and Thorn (1979).

In further joint work on general sample plots on the West Coast of the South Island (Mead *et al.*, 1980), evaluations of fertiliser requirements have been made for a wide variety of sites and soils based on recent surveys and analyses.

Improvement of soil survey technique with particular reference to exotic forest planning.

It is recognised that, on average, trees root more deeply than agricultural crops, can exert greater root pressures, and tap nutrients as well as water at greater depths. Soil surveys which concentrate on these aspects tend to require slightly longer inputs of time, which is often limited, and therefore other aspects of survey should, if possible, be made more efficient. In an effort to do this a point-intercept method for determining and displaying forest soil variability was tested in the Karamea Region, West Coast, South Island (Mew *et al.*, 1980) as part of a data provision exercise for assessing exotic conversion potential. Percentages of soils within landform units (± 6-11% at 95% confidence limits) were shown on a map, and their distribution pattern was illustrated by means of cross-sections.

Establishment of better methods for integrating soils information into forestry planning

Although the McHarg technique of sieve planning has been known for some time (McHarg, 1969), its possible use in New Zealand for forestry planning was not discussed until 1974 (Kirkland, 1974). Subsequent to that, a modification of the technique was found to be an effective tool for planning in the West Coast beech project area. Sieve planning for a 37.5 km^2 area chosen to illustrate the method was described by Mew and Johnston (1979).

In the chosen area soil maps were used as the basis of sieve planning. Three potential options for forest use were considered: indigenous forest management; conversion to exotic forest; use of forests for recreation. Basic information on soils was used mainly in formulating ranking criteria for the conversion to exotic forest option. Three rankings of the physical suitability of the soils for the growth of exotic trees were developed. Criteria for ranking indigenous forest management were based mainly on species composition and the known regenerative potential of particular tree species. Because of the multiplicity of possible recreational pursuits, sub-ranking on the basis of aesthetic value, historic interest and potential for hunting, fishing and tramping was employed.

The technique makes use of transparent overlays, one for each use or value of concern in forest management. For each particular use or value, an hierarchical ranking is established and each of three rankings are depicted by different degrees of intensity of line shading. The relative importance of all uses and values can be seen when all overlays are placed one on top of each other to form a combination overlay. It is possible to identify areas best suited to a particular use or having a particular value, areas where various uses are co-dominant and to some degree compatible, and areas where there is unresolved conflict. Sieve planning allows the stages in the decision-making process to be studied, and objective methods of assessment to be developed. Thus, by using an input of specialist information such as that derived from soil surveys, a sound base for generalised planning can be provided which can be readily appreciated by specialists and non-specialists.

SOILS INFORMATION IN PLANNING FOR THE FUTURE OF EXOTIC FORESTRY

The types of soils data that are currently collected, and the ways in which these data are presented and interpreted for possible exotic forestry use, have been outlined above. As the demand for information has grown, so have the methods of conveying it diversified. This trend has both good and bad aspects. While it allows for inventiveness and improvement in information transfer, it also makes comparison between areas and methods extremely difficult. As yet, no national ranking system of soils for exotic forestry, which links site index to particular suitability classes with specified limitations, has evolved. This may be one of the most important fields where future effort should be concentrated. New exotic forests will continue to be planted, although possibly on a smaller scale than before (Levack, 1979). Attempts will also be made to improve production in older forests. Some of the ways in which further soils information can be provided to help both these future needs in the exotic forestry sphere are as follows:

Extended soil mapping at both medium and large scales

As shown above, soil maps convey much more information than just the areal distribution of soils. At the medium scale, and with suitable interpretative data, they can be used by the forest manager to balance the lack of problems in "good" soils for forestry against, for example, distance from markets or other economic factors. (Further development of quantitative criteria for assessing suitability and limitations will assist here). Thus, if a soil survey is carried out at an early stage of planning, with good liaison between soil scientists and forest managers, the exercise can be of major benefit in determining the viability of the future forest. Re-survey of older forests using advanced techniques could be of benefit in many instances to determine advantages or disadvantages of new forestry methods.

Detailed surveys at large scales can be made where specific soil problems are suspected or known, to aid in the selection of both long- and short-term exotic forest trial sites, and to determine the soil pattern in trial sites already established.

Extended chemical and physical characterisation of soil properties specifically related to exotic forest growth

While it is recognised that most of the development work on tree nutrition is within the scope of FRI, soils are sampled in the course of all soil surveys to characterise the soil units, and more analyses relevant to exotic forestry could be made. Liaison would be necessary to ensure that the most relevant analyses linked to tree growth were carried out.

Particle size analyses are also available for most sampled soils. However, there is much scope for closer links between forestry and soil scientists in the investigation of the relevance of other physical and engineering measurements to potential exotic tree growth (for example, root penetration studies). Routine measurements on samples collected during soil surveys could considerably extend the data base and lead to increasingly objective statements about, for example, site indices.

Greater input of soils information prior to, and in the course of setting up exotic forestry trials

Establishment of unity of soil and site factors, or a detailed examination of their variability, is recognised as being basic to all further trial work.

Improvement of methods of integrating soils information into exotic forest planning

It has been shown in the preceding discussion that a number of different methods for documenting and displaying information of use in exotic forest planning have evolved during the past 20 years, from written descriptions in texts to the visual methods of sieve overlays. Sieve planning, with soil information as an integral part, would seem to be a logical means of data transfer and comparison with other potential uses for the immediate future, backed up by accessible factual tables.

However, considerable work is needed to determine and assemble the factual soil and climatic data necessary to derive a model for predicting the growth of exotic forest species. There is also a limitation on existing soil and other land resource maps because of the inherent variability within the mapping units, especially on hilly and steep land. New Zealand and overseas work has shown that this can be quite significant and could be important in terms of forest growth predictions. In addition, the criteria used for separation of the basic soil units in a survey, especially at a smaller scale, may not include, or may straddle, properties which are significant to forest growth.

To overcome these limitations of map variability and variation of significant properties within soil units, research is under way at Soil Bureau (Soil Bureau Staff, 1980) to produce interpretative maps for specific purposes direct from the point data that are observed or measured during a soil survey. This avoids relying only on mapped boundaries, and not using much critical detailed information that has been gathered. The data which are important and directly related to forest growth can be computer retrieved and sorted, so that detailed maps recording significant soil properties, or groupings of individual properties, can be rapidly produced on colour graphic screens. Recording of these maps on Polaroid colour film is feasible so that "one off" maps can be produced and studied at leisure.

Thus, provided relevant basic soils information at the correct interval for the survey scale being used is collected and stored, it should be possible to combine forestry trial data, climatic data and soil parameters in a form that will give better predictions of growth at many more sites than was previously possible.

Improved person-to-person communication

In an age of increasingly sophisticated microelectronics and telemetry, the human factor must not be forgotten. Person-to-person liaison between forest managers and soil scientists is essential if progress in providing soils information for exotic forest planning is to be maintained. Social and economic factors are also both of major importance in planning and, while these are beyond the scope of the soil scientist, he or she must be sympathetic in interactions with them. Forums such as the Forestry Conference* provide the opportunity for such integrated discussion.

CONCLUSION

Soils information in many and varied forms is basic to exotic forest planning. In an expanding forestry situation, whether for export timber products from more efficient existing forests, energy production, or the planting of new forests on land about which there is currently little knowledge, use of diverse kinds of soils information must be made.

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