Applications of soil survey to farm forestry site selection and management

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Abstract

Trees are being established on substantial areas of Australian farmland for both land-conservation (salinity and erosion control) and profit. It is essential that site constraints are identified prior to planting, so that the trees are planted where they will survive and grow well. Both the environmental benefits of high water use and commercial viability depend on adequate growth.

This paper describes the application of soil survey to farm forestry. Soil survey has advantages in that it can provide information in a relatively cheap and timely manner. Whereas in the past it has mainly been used for the prediction of tree performance it can be extended to form the basis for site-specific management. Management decisions can be made on the basis of actual crop requirement rather than general prescription. Sites with un-manageable constraints (e.g. with shallow or saline soils) can be avoided; those with manageable constraints (e.g. poor fertility, poor drainage, root constraints from shallow pans) can be treated as required.

Much Australian soil survey has relied on observations and interpretations of soil morphology, on the basis that this provides surrogates of underlying factors. In some cases this assumption does not hold and here site assessment procedures should incorporate field and laboratory measurements of pertinent chemical and physical attributes. A pragmatic approach to field survey is required, with data gathering (whether morphological or analytical) being based on demonstrated benefit rather than routine prescription or tradition. Calibration of soil morphological, physical and chemical attributes with tree performance provides considerable research opportunities.

Introduction

The establishment of trees on farmland represents a major change in land use in Australia. In Western Australia alone it is estimated that 90 000 ha of trees have been planted on farmland, since 1985, with a present rate of establishment of around 20 000 ha/year. These trees are being established both for land-conservation and profit. Having a commercial outcome allows tree planting, and hence land conservation, to be funded by investment rather than subsidy (Shea and Hewitt 1997).

Plantings have until recently been concentrated in the >600 mm rainfall zone, with species such as Eucalyptus globulus, Pinus radiata and Pinus pinaster. In the future, large areas of tree...
planting will also occur in the <600 mm rainfall zone as part of the State Salinity Strategy (State Salinity Strategy 1996), with Pinus pinaster and various oil mallee species.

For this programme to succeed it is essential that the trees are planted in areas where they are both profitable and provide the greatest environmental benefit. Major issues thus revolve around identifying (a) sites where trees will not survive, or grow poorly, (b) site constraints that require specific management and (c) where trees should be planted to maximise land conservation benefits.

In this paper we describe the applications for soil survey in resolving these problems. Particular issues covered include (a) a description of the soil information requirements of farm-forestry and (b) the degree to which soil survey can realistically meet these requirements and (c) some future research challenges.

**Soil information requirements for farm forestry**

The evaluation of land prior to the establishment of trees is commonly termed “site assessment” (Valentine 1986) and is a well recognised prelude to plantation establishment in many countries. This has also always been an integral part of both CALM’s and its predecessor the Forests Department’s systems of plantation establishment. Where applied in Western Australia site assessment has mainly concentrated on the prediction of tree performance (particularly survival and growth) (Havel 1968; Inions 1991; McGrath et al. 1991; Edwards and Harper 1996) for pre-selected species. Site assessment has variously involved combinations of soil, climatic, vegetation and geomorphic (i.e. slope, aspect) information.

Soil surveys are often advocated as a tool for agricultural land management, and can have a similar role in farm-forestry. Data collected at the site selection stage could, therefore, provide information for an array of other decisions, ranging from site-species matching to modifying

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management both at tree establishment, and through the ensuing rotation (Table 1). Profitability will be increased by applying inputs where they are needed, rather than on a uniform, or prescription basis. This is site-specific silviculture. Examples include only applying fertilizers or deep-ripping where there is likely to be a response, rather than routinely applying these treatments.

**Soil survey**

**Soil survey techniques**

Soil surveys (Dent and Young 1981; Gunn et al. 1988; Nortcliff 1988) and their application to forestry (FAO 1984; Valentine 1986) have been well described. Soil surveys comprise:

- **Soil mapping**
  Description of soils, and determination of their distribution across the landscape.

- **Soil classification**
  The presentation of this information in a form which allows comparisons of soils between different areas. Examples include local soil classifications (“soil types”) and various national and international classification schemes (Isbell 1988).

- **Land evaluation**
  Interpretation of the information for particular uses, such as yield prediction, or application of management inputs. For yield prediction, approaches have included qualitative ratings of particular soil attributes (Baker and Broadfoot 1979) or regression using individual soil and site attributes (Inions 1991; McGrath et al. 1991).

**Using soil morphology as a surrogate for other variables**

The basic premise of soil mapping, and much land evaluation, is that the soil properties observed in the field (such as texture, depth, colour, structure) are related to other underlying factors (Gibbons 1961). Rather than relying on time consuming (and expensive) field and laboratory measurements the values of the factors of interest are inferred from field observations. It is assumed that these observations, and the resultant maps, are replicable between operators.

For example, field texture is related to clay content, which is often in turn related to other factors. In a study at Jerramungup, Harper and Gilkes (1996) found that clay content was related to other properties such as water holding capacity, organic carbon content and potassium fertility and soil management problems such as hardsetting, non-wetting and wind erodibility. As soil mapping units were based on field texture, soil mapping could depict the distribution of these attributes, and possibly be extended to encompass other issues such as the fate of some types of herbicides. The strength of such relationships may vary from area to area, with local calibrations of soil surveys required.

Some variables, however, have a poor relationship or are independent of field properties. In such cases no amount of description or classification in the field will enlighten us as to their distribution (Gibbons 1961). Such variables are often those which have been modified in the soil by past management, or vary markedly over time. At Jerramungup, for example, plant available phosphorus and clay content were poorly related. The P content was mainly
determined by past fertilizer applications, hence soil mapping was not useful for depicting the distribution of that variable.

Interpretation of soil information

A traditional approach has been to interpret field information through qualitative ratings (FAO 1984; Wells and King 1989). For some attributes this approach is relatively straightforward, whereas for others there may, as discussed, be no underlying relationships between the field observations and the factors of interest.

Field survey information has been useful in explaining tree performance. Soil depth is a surrogate of water holding capacity and a depth of at least 2 m is necessary for reasonable survival of *E. globulus* (R. Harper, unpubl.). Survival and growth of *P. radiata* increases with increasing soil depth (McGrath et al. 1991). Similarly, Edwards and Harper (1996) found marked differences in the height of *E. globulus* between classes derived with the Factual Key (Northcote 1979), a classification based on field properties. It is not always clear, however, what defines a root-restrictive layer and hence the effective depth of the soil.

Field inspections may also readily identify cemented pans, in terms of depth, thickness, continuity and distribution and judge whether ripping is appropriate. In contrast, this approach may not identify compacted layers in sands, and hence allow prediction of ripping response. Similarly, it may not tell us anything about soil fertility or salinity. Where such poor, or ill defined relationships exist a more appropriate strategy is to sample the soil and measure the attribute through physical or chemical analyses. Tree response thus needs to be calibrated with soil properties, either described or measured, and this is an active area of research within CALM.

This has long been recognised in agriculture with fertilizers applied in response to soil chemical analyses, rather than soil survey. Responses to fertilization can be calibrated with soil nutrient concentrations. These calibrations are likely to differ between species. For example, *E. globulus* growing on sandy soils does not appear to respond to phosphorus applications where bic-P concentrations are >3 µg g⁻¹ in surface soil (J. McGrath, unpubl), whereas such low concentrations result in severe P deficiencies in crops in pastures.

Salinity is a major issue in Western Australia, is not adequately defined by traditional field inspections. The current salinity of the soil is assessed using either soil analysis or more commonly field electromagnetic techniques (Bennett and George 1995), as these allow more intensive sampling. Prediction of future risk of salinity due to rising groundwater tables is more problematic, and requires hydrological understanding.

Determining soil distribution

Although estimates of tree performance, and the other factors in Table 1, are often made for individual points, what is of most concern is how areas of land will perform. Soil survey provides techniques which allow extension of point information into areas.

There are two major approaches to soil mapping. The first involves routinely sampling the properties of concern in a grid and then interpolating between observations. The other, in the technique of “free survey”, relies on developing an understanding of how soil properties vary across the landscape. Such systematic variation can occur in response to landscape processes,
such as occur along slopes. Understanding these processes, and hence patterns, can lead to much more efficient sampling schemes, based on interpretation of aerial photography.

**Discussion**

In Western Australia there has been a strong reliance on soil surveys which characterise soils on the basis of soil morphology alone, classify the soils into “soil types”, map the distribution of these “soil types” across the landscape and provide subjective evaluations. This approach was probably adequate when the ability to manipulate spatial and point data was limited, however with data-bases and geographic information systems these obstacles have now been overcome.

Currently CALM’s farm forestry soil survey (Harper 1994; Harper 1995) relies on a staged approach. Initially a range of issues such as climate, slopes and land-holder preference are considered, to identify target areas. These areas are then surveyed and areas with limitations likely to affect tree performance, such as shallow, saline, waterlogged or grossly nutrient deficient soils are identified. On sites where trees are considered likely to survive, tree performance is considered in terms of the effects on water supply (deficiency or excess) and site fertility. Tree growth can be predicted from key soil and site variables (Inions 1991; McGrath et al. 1991; Edwards and Harper 1996). Fertilizer requirement can be estimated from soil analysis.

The scale of existing soil surveys (1:50 000-1:100 000) is too broad, compared with what is needed for individual paddock management, thus farms are surveyed at a larger scale (1:10 000-1:20 000). Similarly, field observations are routinely made to depths of 2-3 m, an approach which can be contrasted with agricultural surveys which usually only consider the surface metre.

Another set of issues relates to the placement of trees in the landscape, for greatest environmental benefit. The problem of where to plant trees for wind erosion control is relatively straightforward, as wind erodible soils can be identified relatively easily. Salinity, however, is a hydrological problem and there appear to be major difficulties in predicting its distribution in the landscape and where to plant trees to control it expression. In this case the role of soil surveys may be to provide some inputs for hydrological models, rather than directly solving the problem.

As the time and resources available to undertake farm forestry soil surveys are limited, data gathering has to focus on those attributes which have demonstrated importance in terms of the framework provided in Table 1. As already described, soil morphology may not adequately describe all factors of interest. A pragmatic approach to field assessment is thus required using a combination of techniques, including soil morphology and an array of pertinent physical and chemical measurements. Some attributes (pH, salinity) may be measured in the field, whereas others (soil fertility) will require laboratory analysis. Information requirements from soil surveys will evolve, as models which describe factors such as diverse as tree yield, landscape water movement and herbicide sorption are refined, and key input attributes identified.

Successful site-specific farm forestry will require the calibration of various soil conditions with tree performance, and it is here that considerable research opportunities arise.
References


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