Site evaluation for farm forestry: a tool for land selection and management

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1. Introduction

CALM is currently involved with five major afforestation schemes (viz. *Eucalyptus globulus* with the Hansol, Oji and Mitsui joint ventures, *Pinus pinaster* sharefarms, and second rotation *Pinus radiata*), which aim to establish ~17 000 ha of plantations each year. Possibly 35-40 000 ha of land will have to be assessed each year to ensure that suitable land is planted.

These trees will be planted both as traditional block plantations, and also as strips or shelter-belts integrated with farming (Shea and Bartle 1988). For the purposes of this report, however, all will be referred to as "plantations", although the different planting systems may have different land evaluation requirements.

The traditional plantations are aimed at producing timber and pulp, while the shelter-belts are often planted to provide land conservation benefits, such as the reduction of salinity or the provision of windbreaks, for soil and livestock protection. Wood production in these areas is often a secondary consideration. Salinity is a major land degradation problem in the south-west of Western Australia (Select Committee into Land Conservation 1990), and tree planting is often advocated as the only practical option for salinity control (Schofield 1992). Tree species most commonly planted are *E. globulus*, *P. radiata* and *P. pinaster* as they provide utilizable products.

The dependence of tree survival and growth, on soil and site conditions is well known, and these factors are often assessed by the techniques of land evaluation (FAO 1984; Valentine 1986). Although estimates of tree performance 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 (Burrough 1993).

2. Site evaluation in CALM

Site evaluation has always been an integral part of both CALM's and the Forests Department's systems of plantation establishment. Examples of such systems include those for *P. pinaster* (Havel 1968), *P. radiata* (O'Donnell and Lockhart 1945; Clifton 1966; McCutcheon 1978; McGrath *et al.* 1991) and *E. globulus* (Inions 1991). Similarly, site evaluation systems are a well recognised prelude to plantation establishment in many overseas countries (Valentine 1986).

The value of such information has long been recognised with Prof. Earl Stone (1982) for example stating "If an organization cannot afford the insurance provided by soil mapping and interpretation it cannot afford the risks of investing in plantation establishment...".

An array of land evaluation techniques is used within CALM:

E. globulus: *E. globulus* Growth Simulator (EGGS) (Inions 1991) prediction, combined with depth drilling and EM38 measurements

P. pinaster: Soil survey and land evaluation (Harper 1995)

P. radiata: (Second rotation) Local practice

New standards were developed for soil surveys for *P. radiata* sharefarms in 1991 (Harper 1991), and these were tendered out. Following consideration of the costs of the tender ($10/ha) and the annual area surveyed (~7 000 ha), two staff within Science and Information Division (Technical Officers Ward and Reilly) were trained in the techniques of soil survey, and have undertaken this work for *P. radiata* and *P. pinaster* sharefarms since.

3. Potential uses of site evaluation information (Soil specific silviculture)

Site evaluation has been used mainly for the prediction of yield, however it can also aid plantation management through the life of the rotation.

Plantation profitability will be increased by applying inputs where they are needed, rather than on a uniform, or prescription basis. This is soil-specific silviculture.

Examples include:

- identification of hazards (drought, flooding, salinity, windthrow)
- silvicultural treatments (ripping, mounding and draining)
- prediction of erosion (water and wind) hazards at plantation establishment
- trafficability at harvest
- reducing any environmental impact of plantations (nutrient and herbicide leaching hazard, fate of run-off waters)
- matching tree species with site conditions

Similarly, trees are often integrated into farmland, with the plantings aimed at producing land conservation benefits, such as:

- the control of salinity and waterlogging

- wind breaks for soil, crop and livestock protection
- habitat for wildlife

A range of site information is required for this integration to occur on a rational basis, and to maximise their benefits.

Similarly, although this information is not necessarily known now (such as responses to ripping or mounding on different soils), the site evaluation system will provide a framework for future research.

4. Site properties in relation to wood production

The role of sites in affecting tree performance can be considered in terms of their effects on water supply (deficiency or excess), tree nutrition and stability (Carmean 1975; Valentine 1986; Turvey *et al.* 1990), and hazards such as salinity (Bennett and George 1994).

4.1. Water supply

In south-west WA both water deficiency (drought) and excess (waterlogging) are important for tree performance. Deficiency will be related to the volume of the soil, its moisture holding capacity and rainfall. Factors which control the moisture holding capacity of the soil include the depth to root impeding layers such basement rock or hardpans and soil texture. Moisture supply can also be dependent on local hydrology. Drought deaths are periodically reported in areas with shallow soil, and where root exploration of sub-soils is limited. Examples include deaths of *P. radiata* (McGrath *et al.* 1991), and *E. globulus* (Harper 1994), on shallow soils in dissected river valleys in the Yilgarn Block and on *P. pinaster* on sand dunes with limestone cores on the Swan Coastal Plain (E. Hopkins pers. comm).

Waterlogging has been recognised as a problem in agricultural regions of south-western Australia (McFarlane *et al.* 1989), particularly on duplex soils. An excess of water can lead to anaerobic conditions, death of tree roots, and paradoxically drought deaths in the following summer. Similarly, trees in such sites can suffer from wind-throw.

The pattern of water supply is often related to landscape position (Moore *et al.* 1991), with water logged sites most likely in lower slope positions and at the breaks of slope.

4.2. Nutrition

Deep weathering and deposition have resulted in soils comprised mainly of quartz with kaolinitic and sesquioxide clay minerals (Gilkes *et al.* 1973; Robson and Gilkes 1981). Consequently soils are infertile in terms of a range of plant nutrients, with forestry responses to both macro (N, P, K) and micronutrients

(Cu, Zn, Mn). Chemical fertility is invariably higher on soils under agricultural management, compared to native vegetation, with contents of nitrogen and phosphorus often related to past management. Soils with potassium deficiencies are often sandy, and excessively drained and may not be capable of producing economic timber crops. While calibrations between different chemical extractants and plant response have been developed for phosphorus and potassium for agricultural plants, such relationships are not available for commercial tree species.

4.3. Salinity

Salinity is a major agricultural land degradation problem in south-western Western Australia (Select Committee into Land Conservation 1990). This is a consequence of the storage of large amounts of salt within the deep weathering profiles; this salt is remobilized by movements in groundwater following land clearing for agriculture.

Measurements of salinity at a site may be less important than understanding the likely response of deep groundwaters over time. In areas with ≈750 mm annual rainfall groundwaters can rise at rates of up to 1.4 m/year (Schofield *et al.* 1988), and salinity may even develop following tree establishment. Hence, direct soil measurements may not be relevant as the quantities of water stored in the soil profile changes over time.

5. Costs and returns of site surveys

Plantation performance has been shown to be affected by soil conditions in several recent studies:

- Drought deaths have occurred in many CALM and private plantations in the last two years, and these can often be related to soil conditions. For example, in three hills plantations plots with >2 m soil depth had 71% survival, at age five, compared to 35% survival in those <2 m deep (Harper 1994).
- Tree growth and survival has been related to soil salinity (Bennett and George 1994).
- Productivity can be related to soil type. For example, volume production is consistently poorer on deep sandy soils compared to other soils (Edwards and Harper, in prep).

Economic returns from site surveys will mainly accrue from the avoidance of sites where tree survival will be poor, but also from better prediction of site productivity as a basis of sharefarming contracts and tailoring management inputs according to site requirement. Similarly, non-economic returns will accrue by optimising the land-conservation benefits of trees.

The costs of site surveys, as proposed in this report will be approximately $15-20/ha. The cost will increase with increased intensity of field observations, and more detailed assessments of site hydrology.

6. Site survey as an integrated solution to the problem

6.1. All plantations

A diverse array of information is required to fill all the above requirements, and these can be met with the techniques of site survey and evaluation.

Basically, site evaluation can be considered as a three stage process:

- *Initial reconnaissance*: In this stage all broad-scale attributes can be assessed, such as climate, broad landform, land-use zoning, drainage
- *Site survey*: This involves an on-site assessment of the property. This includes determining the distribution and properties of the major land management units. For each land management unit an array of information, such as soil depth, fertility, salinity (current status and future risk), hydrology and geomorphology (slopes) will be assembled.
- *Evaluation*: This involves the interpretation of the site survey information. For each of the mapping units a series of evaluations can be made, such as potential productivity, drought risk, silvicultural requirements (ripping, mounding etc), erosion hazards. These can be presented as either tables or maps of individual themes. For example, a map may be used to show the distribution of those soils likely to benefit from ripping, with an area summary, for use with budget calculations.

6.2. Special requirements for shelterbelts and integrated plantings

Apart from wood production, shelterbelts also have the aim of producing environmental benefits to farms, such as the reduction of salinity, waterlogging and wind erosion. To optimize the benefits of any tree plantings it is important that the pattern of potential land degradation is understood. Before any advantage can accrue it has to be clear that there is in fact a problem, and that trees can provide a solution.

Farmers do not however manage their farms for land degradation, but for the production of crops and livestock. Hence, tree plantings will also have to fit into a farm-plan, which takes into account several objectives. It is essential that the site-surveyors have expertise in farm-planning.

7. Specifications for site evaluation for farm forestry

7.1. Aims

Aims of the site surveys are to:

- Identify the area of plantable land via a map of major soils, presented as a series of Land Management Units (LMU).
- For each LMU identify potential productivity, any constraints to tree performance and necessary management inputs.
- Produce parametric maps (i.e. productivity, hardpan distribution, waterlogging hazard) so that management decisions can be made for each LMU.

7.2. Site survey guidelines

These are adapted from various sources (Western 1978; Dent and Young 1981; Valentine 1986; Streit *et al.* 1987; Gunn *et al.* 1988a; Langdon 1991).

7.2.1. Initial reconnaissance

When a property is initially offered for tree planting the general suitability can be derived from local knowledge, and regional soil-landscape mapping such as by Churchward *et al.* (1988), climate and distance from mill or port.

Land availability will also be determined by attributes such as:

- areas with slopes <15%
- streams, roads, powerlines and other easements
- patently unplantable areas such as lakes, salt flats, rock outcrops
- mineral claims and other land tenure issues
- visual impact
- land-holder preference

After these attributes have been determined, the soil survey can proceed if suitable areas of land are considered available.

7.2.2. Site survey

All site survey work should be undertaken using current accepted practice, such as recommended by the Australian Collaborative Land Evaluation Programme (ACLEP) using accepted Australian standards (McDonald *et al.* 1990). This will allow an interface with the spatial information collected by other agencies (i.e. DOLA, Agriculture WA) and the with GIS based management systems under development within CALM (PMAP, PMIS).

- A mapping scale of 1:10 000 will be used, using an aerial photographic enlargement (scale 1:10 000) as a base. If possible this will have been digitally corrected for distortion.

- Mapping will occur using a free survey approach rather than grid technique[1]. Free survey relies both on field observations and an interpretation of both aerial photography and landscapes. Stereo-contact prints are used for air-photo interpretation of major mapping units, based on landforms, prior to field work.

- An observation density of at least 1 hole/ha is required; in some areas (i.e. shallow soils) more observations will be required, in others (i.e. laterite with deep weathering profiles), less. Each observation point will be encoded using a GPS.

- The depth of sampling will be to a depth of at least 2 m. A drill rig will be used.

- At each site observations will be made of the depth of each soil horizon, texture and colour, the nature of any root impenetrable layers, parent rock type, drainage and likely salinity hazard. The will be recorded using Australian standard methods (McDonald *et al.* 1990).

- Salinity will be assessed using a Geonics EM 38 meter, at each field observation point. As the readings from this meter are also affected by soil moisture content, and depth of sand horizon, it should be calibrated for each property surveyed. For a range of 8-10 drill holes across the property, samples should be taken, at 50 cm depth intervals, and submitted to the laboratory for salinity (EC) analysis. Using this calibration, the EM38 readings can be corrected for local variations induced by moisture content, sand horizon depth and other factors. This follows the technique of Lesch (1992). Sites with EM38 values of >25 mS m^{-1} on sandy soils, and >50 mS m^{-1} on other sites should not be planted.

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[1]*Gridding vs free survey:* Gridding allows the use of unskilled personnel, and produces un-biased summaries of soil properties. It has disadvantages in that in some areas excessive sampling will occur and the accuracy of mapping unit boundaries will depend on the grid density. In contrast, free survey allows the surveyor to take into account the nature of the landscape, and the strong relationships which often occur between soils and landforms. The interpretation of these relationships allows the more accurate depiction of soil patterns. Although requiring less observations free survey will require more skilled personnel. These issues are described in more detail elsewhere (Dent and Young 1981; Gunn *et al.* 1988b).

- The risk of future salinity will be determined by reference to landscape position, clearing history and if necessary examination of ground waters. Detailed drilling is not possible at all sites. As a guide sites where the watertable is within 4-5 m of the surface and salty (>2000 mS m^{-1}) should not be planted. Hydrological advice should be sought where considered necessary.

- A back-hoe examination of soils will be required in some instances. Although a drill rig will be used, this will be inadequate in some situations, such as determining if ferricrete (ironstone) pans are continuous, or the nature of sub-soil clays. Both situations may affect tree growth and survival .

- Land Management Units will be developed from this information and air-photo interpretation. These will comprise groups of soils which are likely to perform in a similar manner. Hence, for each mapping unit it will be expected that there will be differences in likely tree performance or management inputs. A minium management area of 1 ha will be used.

7.2.3. Interpretation.

- The LMU will be interpreted for a number of aspects such as likely tree survival and productivity, silvicultural requirements, environmental considerations. These interpretations will be summarized as specialised maps and summary tables. From these economic analysis of plantation can proceed. Similarly, an estimate of the suitable planting area can be prepared, and a proposal made to the land-holder.

- For those properties where a plantation will be proceeded with, the site survey information will be entered onto a geographic information system (GIS). Information Management Branch are developing plantation management information systems (PMAP, PMIS), which will contain all relevant information about the property.

- Specialized interpretations will be required for the integration of strips and blocks of trees onto farms, to take into account farm infrastructure, water movement and optimising land conservation benefits of tree planting. This may proceed in a different way to the selection and planting of a large traditional plantation. Particular soils, for example, may be unproductive under agriculture (i.e. deep sands) but be nominated for forestry. Specialized skills are required for such interpretations.

- Soil samples (0-10 cm deep, 20 sub-samples) will be taken from the LMU which will be planted and assessed for available phosphorus (bic-P), potassium and organic carbon. These will provide basis for broad fertiliser recommendations.

7.3. Staffing and equipment requirements to undertake site evaluation within CALM

I suggest that the necessary site evaluation for new plantations, can be undertaken within CALM. For this to occur, however, will require a dedicated unit with some specialized equipment. As the site surveys are seasonal, those staff involved could be attached to other programmes for the remainder to the year.

7.3.1. Staffing Structure

I suggest the following structure:

- 1 L4 Site Survey Supervisor, who will check all surveys, undertake some property evaluations, maintain standards, implement new techniques, carry out training, and co-ordinate work programmes and budget
- 3-4 specialist site surveyors (L2 or 3) (one attached to each major tree planting scheme). These staff will undertake site surveys, as required, and either undertake other duties within Sharefarms or Science and Information programmes. As site survey techniques are specialized, it is important that staff selected for this role can be allowed to develop expertise over several years. Duties will include field surveys, digitisation of field information and interpretation of mapping units. Safety considerations with the use of a drill rig, will mean that these surveyors should be accompanied during field survey by another staff member.
- Support from FMB and IMB, particularly with the supply of rectified base photography for each property, access to GIS and production of theme maps.

7.3.2. Training:

7.3.2.1. Field surveyors

Field surveyors will need training. This will include:

- Overview of major soils in different areas of the south-west, and how these relate to geology and geomorphology. Basics of hydrology.
- Training in specific techniques such as aerial-photograph interpretation (as related to soils and landforms)
- Objective description of soils (colour, texture), landform according to the techniques of McDonald *et al.* (1990).
- Data management and interpretation

- Interpretation of site information, based on current research information, such as likely survival and productivity of trees, silvicultural requirements, erosion hazards
- Farm-planning and the placement of trees on farms for land-conservation purposes.

Some training will involve formal courses, some be on-the-job.

7.3.2.2. Field managers

Training will also be required for field managers to help interpret the site survey information and maximise its benefits.

7.3.3. Equipment

An array of equipment is required, some already existing in CALM.

Each of the site evaluation teams should have the following equipment:

- Drill rig (such as that used by Wellington Share-farms), mounted on tray of 4WD
- GPS unit, EM38
- Lap-top PC
- A collection of geological and soil maps
- Field equipment such as soil colour charts, shovels etc

Also:

- Access to a GIS to allow digitisation of field line-work and calculation of LMU areas
- Backhoe examinations of sub-soils are essential in some situations, such as where a root-limiting hard-pan may occur. These will be hired from local contractors.

8. Technologi cal Developments

With the advent of new technologies, land evaluation is currently undergoing a revolution. Some of these technologies can be used now, with little modification:

- the presentation, and manipulation of spatial data on geographical information systems (GIS) (Burrough 1986; Burrough 1993)
- field data capture

Techniques which may be useful in the medium term (5-10 years) include:

- geophysical techniques (magnetics, apparent electrical conductivity, gravity, ground penetrating radar). These have been advocated for use in predicting the distribution of salinity.
- the use of terrain models to estimate the distribution of water (Moore *et al.* 1991; Dawes and Hatton 1993) and different soil attributes (Skidmore *et al.* 1991; Moore *et al.* 1993)
- numeric techniques such as kriging which allow interpolation of point data (Webster 1985; Webster and Oliver 1990) and application of classification and regression models (Burrough *et al.* 1992; McKenzie and Austin 1993)

Some techniques should be regarded as experimental, with their application awaiting the results of tests to demonstrate their utility in forestry land evaluation. Kriging for example may be useful in delineating single soil attributes such as depth to a root impenetrable layer, where this attribute can be measured relatively simply and cheaply, but will be limited where expensive chemical analysis are required.

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