



Department of  
**AGRICULTURE  
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AUSTRALIA**



**The Development of an Effective Methodology  
to  
Capture Forest Type, Condition and Volume Data  
for  
Privately Managed Forests**

**Report of a Scoping Study  
for the  
Forest and Wood Products Research and Development  
Corporation**

**By**

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## Table of Contents.

	Page
Executive Summary .....	3
Research Needs .....	6
1. Introduction.....	8
1.1 Preamble.....	8
1.2 Montreal Criteria and Indicators .....	9
1.3 Terminology and Definitions .....	9
2. Current situation.....	10
2.1 Current methodologies and technologies.....	10
2.1.1 Tasmania .....	11
2.1.2 Victoria.....	11
2.1.3 South Australia.....	12
2.1.4 Queensland .....	12
2.1.5 Western Australia.....	14
2.1.6 New South Wales.....	15
2.1.7 Summary Comments .....	15
2.2 Data processing for private forests.....	16
3. Evaluation and review of current practices.....	16
4. Management Objectives and Intentions .....	17
5. Common Elements to Future Inventory Design.....	18
5.1 The changing context of inventory information.....	18
5.2 Maintaining regional and national data .....	19
5.3 Inventory design .....	19
5.3.1 Area classification .....	20
5.3.2 Spatial data .....	20
5.3.3 Attribute data collection .....	20
5.3.4 Multi-stage inventories.....	24
6. Data Processing and Implementation .....	24
6.1 Data processing .....	24
6.2 Implementation.....	25
7. Differentiating between Native Forests and Plantations .....	25
8. Recommendations and Research Needs.....	28
8.1 Research Needs .....	29
9. Literature Cited.....	31

Appendix I, Montreal Criteria and Indicators considered relevant to this study.

Appendix II, Consultation.

## Executive Summary

This report was commissioned by the FWPRDC to develop effective methodologies to capture forest type, condition and volume data for privately managed forest throughout Australia. The objectives of the study were to identify current techniques, scope the development of a cost-effective, standard method suitable for use throughout Australia and, where new methods cannot be developed, identify research priorities.

Australia's forests cover a wide range of categories. Privately managed forests, as indicated by the brief, can be defined as privately owned and publicly owned but privately leased. These forests total approximately sixty-nine percent of Australia's total forest estate. Adequate information is available for the private plantation resource but little is known about the privately managed native forests. Appropriate and consistent data at the regional level would greatly assist planning activities at both the regional and national level. For the relatively few individual growers collecting inventory data, use of a standard protocol would enable integration of the local data into the regional and national level frameworks. A more consistent approach to inventory across the three levels would therefore be advantageous even if varied in intensity. However it is recognised that a practical application of the proposed protocol may be difficult and a number of issues need to be worked out to ensure that it can be applied.

In developing a methodology, the measurement data and/or determination of protocols should be consistent with the Montreal Criteria and Indicators. Some of the indicators are imprecise in their definition and need refinement at less than regional level. Furthermore, this scoping study does not address the issues required for monitoring the Montreal Criteria; growth being an important omission, which is vital in the determination of sustainability.

Productivity, an indicator of growth potential, is usually calculated from a number of measurable parameters and its definition, determination and subsequent consistent mapping depend on a whole range of site and stand characteristics such as soils, species, past treatments. Similarly, biometric techniques, especially those for estimating assortment volumes by product and quality, need considerable research. All of these issues are extremely important both for owners and for all levels of management but are beyond the bounds of this study, which is involved with inventory methodology. Therefore, it is strongly recommended that a separate study be initiated to investigate these areas of research and development.

Management intent is also an important issue for any inventory. Management intent of privately managed forests varies considerably with size of the resource, the owners' objectives, and prevailing government regulations. The inventory methodology finally adopted will therefore have to include a survey of management intent in order to translate the estimates of standing volumes into volumes likely to be made available for sale at a particular point of time.

In general, inventory methods applied to privately managed forests have been adapted from those used by Government agencies.

Those used for privately managed plantations appear adequate for the larger organisations and/or cooperatives but are proving expensive to maintain. Furthermore, they are not readily applicable for small privately managed estates.

Very little inventory is carried out relative to the total area of privately managed native forests. However, broad scale (1:100,000) mapping of forest areas has been carried out and does address some of the regional and national needs.

Area and volume estimates are available for some privately managed forests and plantations, but are mostly restricted to the larger plantation or native forest estates or co-operatives.

Operational inventories of privately managed native forests at the more intensive level are generally opportunistic, fragmented varied in design and protocols, and of varying levels of precision. They are therefore limited in their use at the regional and national levels.

Existing methodologies relevant to this study are those developed for the CRA/RFA process in South East Queensland and the private forest inventory and management intent survey used in Tasmania.

One common inventory procedure cannot be implemented for all privately managed forests throughout Australia due to organisational differences, historical reasons, the intensity and related cost of inventory work for different objectives, and the differences in the owners' intents.

Thus a general protocol is suggested to provide relevant information and address both the operational and regional needs for sustainable forest management. A systematic and consistent storage of information, at regional and national levels is required, with appropriate indices of precision. Given such a system and protocol, the design of inventories can be tailored to meet the particular objectives of the owner as well as providing appropriate data at regional and national levels.

The protocol deals with three distinct stages

- mapping of forest areas,
- attribute data collection using both remote sensing and field-based sampling, and
- surveying of management intent.

To gain a more quantitative understanding of Australia's forest resource, spatial and non-spatial data needs to be accumulated for the entire forest estate for a number of attributes including; forest cover, land tenure, forest type, age (age class), stocking, height, standing volume, and condition.

A multi-level approach needs to be adopted based on the use of both remote sensing and field-based sampling, subject to a minimum sampling level considered acceptable for regional and national purposes.

For the entire forest estate, spatial and non spatial data needs to be accumulated and then further subdivided according to owner's long term objectives and short term intent. The following subdivision is suggested.

- Non-forest or forest land, with forest land further categorised by forest type and condition.
- Apparent objectives. For example,- government including reserves, privately managed commercial, privately managed non-commercial.
- Management intent. For example, commercial harvesting intended in next five years, commercial but withheld from harvesting for next five years.

This subdivision will need refinement in the light of a separate survey to ascertain apparent objectives and management intent, but the principles will be apparent from the examples above.

Area data can be collected through a variety of tools ranging from satellite imagery to ground based survey. Research is required to address their integration in forest planning, how the measurements should best be conducted, and to define the goals for spatial precision and freedom from bias.

GIS is recommended for the management of large spatial data sets, especially for growers or cooperatives with estates greater than 1,000 hectares, and for regional and national level data. However, standards need to be specified concerning scales for data entry to ensure spatial compatibility when aggregating data to the regional and national levels.

A protocol that facilitates the collection of standard resources data for different management planning levels needs to be developed which would encourage owner input to the scheme even where the owners' management intent is to "do nothing".

A number of statistical techniques are available for the efficient collection of attribute data. A multi-stage approach using remote sensing is likely to be useful for stratification. Different but appropriate technologies for sampling could be employed at each stage, for example satellite imagery for the first stage and aerial photographic interpretation for the second stage.

Multi-stage sampling has the advantage of concentrating work on specific samples of interest. The technique is particularly useful where primary sampling units vary in importance (for the parameter/s being estimated) and allows further sampling to be concentrated in areas of greater significance with respect to the parameters being estimated. The choice of technology and sampling intensity at each stage is related to available funds, scale and management intent.

Education and promotion of the overall scheme is of paramount importance to encourage local inventory programs and will require considerable funding and time. Costs can be reduced by targeting existing grower cooperatives (for example the Regional Plantation Committees) and encouraging the establishment of new ones.

Some economies of scale can be effected through the NFI, for example the purchase of regional or multi regional remote sensing data or the provision of suitable processing systems (spatial and attribute) where individual small owners are unable to provide their own systems.

Because Australia has a large area of forest it is not considered practical to implement separate inventories at all planning levels. An approach is required that integrates national, regional and operational forest management planning. A multi level approach is recommended that has the objectives of providing;

- At the operational level, sufficient detail for an owner to meet the basic requirements for regional sustainable forest management, and,
- At the regional or at a broader scale, consistent and suitably precise information, relatively free of bias, for regional sustainable forest management.

The protocol should also apply to government managed forest, including reserves and parks, which have sometimes been neglected in the past.

It is recommended that a pilot study be set up, to build on the findings of this study and more thoroughly design a mapping and sampling protocol for operational, regional and national inventory.

### ***Research Needs***

The following research needs have been identified but are not in any order of priority because different aspects are likely to be funded and carried out by different agencies.

1. More efficient and cost effective methods for stand stratification are needed. Remote sensing technologies offer considerable scope but the following issues needs to be addressed
  - Remote sensing and GIS technologies need to be integrated fully into planning,
  - No single remote sensing platform is capable of resolving inventory requirements (FWPRDC Application of Remote Sensing to Forestry study), and thus greater attention needs to be given to combining these technologies with other methods of stand stratification, including the possible integration with environmental data such as terrain, climate and soils, and,
  - The use of radar technology to gather cloud-free imagery for forest mapping.
2. Given the fragmented nature of the private resource, research is needed to investigate the use of new forms of remote sensing to supplement and/or replace data that has traditionally been collected by field sampling. Technologies such as the use of digital frame cameras, digital video, laser profiling and differential global positioning systems, all offer considerable scope.
3. Reporting of the errors of estimates and the level of accuracy (or precision) needs to be standardised, both for spatial and attribute information.
4. Research is needed into the mapping of forest communities, especially for biodiversity management.
5. At the operational level, there is a need for product quality information. Research is needed to improve the efficiency of attaining product and product quality estimates.

6. Field sampling techniques should continue to be developed and tested, including continuation of the development of p-3P and centroid sampling.
7. The design of surveys to ascertain owners' objectives and management intents needs research. These are social surveys and need sociological input.
8. Research is needed to develop generic growth models. The availability of data and the balance between different modelling techniques in order to meet completely different objectives needs to be considered in selecting appropriate models for different regions.
9. A consistent approach to mapping plantation productivity is highly desirable at least on a region by region basis.
10. Local cooperatives need to urge owners (in particular owners of smaller forest estates) to undertake more intensive inventory and management of their forest.

In addition, there are serious concerns about computing technology.

The development of computer systems is expensive. Are there better ways of minimising this expense through collaborative development? Suitable systems are generally not available for use by the small private owner. Many larger private owners are using "out-of-date" systems because of the cost of updating and a hiatus in the availability of "off-the-shelf" systems.

Thus, there is a need for;

- A generic base level system that can provide all forest owners and managers with a method of calculating inventory and providing the generic processed information that is required at regional/national level, and,
- A system to manage the processed information across all forested land areas.

This will require substantial funding but would provide information currently not available for sustainable forest management and regional planning.

## **1. Introduction.**

This report was commissioned by the FWPRDC (Forestry and Wood Products Research and Development Corporation) to develop effective methodologies to capture forest type, condition and volume data for privately managed forests throughout Australia.

The objectives of the study (slightly paraphrased from the call for applications) are as follows.

1. Identify current inventory techniques used, or those that may be suitable for use, to measure and monitor the relevant indicators (to meet criteria such as the Montreal criteria). Private forests are fragmented and variable in nature and existing techniques are either expensive or not sensitive enough to capture the required data. Further, they often have different management objectives and are managed to different degrees of intensity compared with public managed forests. Consequently an innovative and flexible approach is required.
2. Develop a cost effective standard method that can be used throughout Australia.
3. Where a suitable method cannot be developed at this stage, or where it needs further evaluation, identify research priorities that need to be addressed in the longer term program.

The objectives of this particular study only address some of the issues required for monitoring the Montreal Criteria. The issue of net growth estimates is an important omission and is vital to sustainability. The determination of site productivity and the estimation of net growth are complex issues, which merit a separate study.

### ***1.1 Preamble***

Australia's forests cover a wide range of categories and incorporate public and private ownership and commercial and non-commercial uses. Privately managed forests consist of privately owned forests (42 million hectares or 27% of the total forest area) and publicly owned but privately leased forests (65 million hectares or 42% of the total forest area). They form a significant proportion of Australia's forests and in some places contribute significant quantities of timber to the domestic and even the international market.

The National Forest Inventory (1997) plantation report provides adequate detailed information for the areas, location, age-class and species, and volumes on privately managed plantations through to 2039. An update of the National Forest Inventory Report is to be made in 1998. However, very little is known about the above attributes for most privately managed native forests.

Appropriate and consistent data at the 'regional' level, detailing what, where, how much, and when wood would be available will greatly assist regional planning of the current resource for economic, environmental and social purposes, including investment into new ventures.

Whatever the owners' (or manager's) long term objectives and immediate intentions are, the extent of the private forest resource needs to be determined at the national level if issues such as carbon balance and biodiversity are to be adequately addressed.

Although this scoping study only addresses one component of the forest resource and the issues relating to privately managed forests, all Australia's forests need to be considered. The study suggests a framework that could be extended to ALL forest land, government or private, whether managed for timber or for other objectives, or not managed at all.

Three general levels of information are considered; operational, regional and national. A consistent approach to inventory information across the levels would be advantageous, even if varied in underlying sampling intensity and design. However a completely uniform system is impractical, uneconomic and would be unacceptable to many forest owners. The approach that is adopted therefore, is to seek to define a consistent protocol for the information required, while leaving scope for variation of sampling intensity and design.

## **1.2 *Montreal Criteria and Indicators***

The primary purpose of this study is to develop an inventory methodology that not only provides basic information on forest type, condition and volume, but more specifically provides information relevant and consistent with the Montreal criteria and indicators for the conservation and sustainable management of Australia's forests. Whilst all the criteria and indicators apply equally to private forests as well as public forests, those criteria seen to be important to this scoping study are listed in Appendix 1 (The Montreal Process, 1995 & 1997).

## **1.3 *Terminology and Definitions***

During the consultations carried out for this study, considerable variation with respect to the understanding and meaning of a number of terms became apparent. The following definitions are therefore offered in an attempt to provide more consistent understanding.

### **1. Forest**

An area dominated by trees having usually a single stem and a mature stand height exceeding 2 metres and with an existing or potential crown cover of overstorey strata of 20 percent or more. This definition includes Australia's diverse native forests and plantations regardless of age. It is also sufficiently broad to encompass areas that are sometimes described as woodlands or mallee formations.

### **2. Forest Type**

A category of forest defined by its vegetation, particularly *canopy* composition. In some circumstances understorey species or type are also included where they enable better definition of the ecosystem.

3. Forests Structure

A category within a forest type that recognises structural entities within and below the canopy

4. Growth

The rate of volume increment of a stand, often measured as Mean Annual Increment (MAI) or Periodic Annual Increment (PAI) in cubic metres of wood per hectare.

5. Privately Managed Forests

Privately owned forested land and privately leased public forested land.

6. Standing volume

The total standing bole volume to defined standards. The primary purpose is to have a standard to which a conversion factor or process can be applied to determine merchantable assortment volumes, or to determine biomass.

## 2. Current situation.

### 2.1 *Current methodologies and technologies.*

Due to the cost of inventory and subsequent data processing, current inventory methodologies used to assess privately managed forests have largely evolved from those used to assess publicly managed forests or those used by larger private plantations.

These methods were recently reviewed by Turner (1992) in a paper titled Stand Inventory Techniques in Australia. Turner reports that:

*Inventory methods in Australia vary with the purpose of the inventory, forest type and land tenure. The definition of a stand for inventory purposes also varies. Stands in the native eucalypt forests are usually defined from aerial photography. In the oldgrowth forests, operational inventory is by strips or line plots whereas in the regrowth or selectively-managed forests a systematic or stratified random allocation of plots, sometimes concentric or variable radius, is used. In coniferous plantations, plots are usually 0.04 ha rectangular in systematic or sometimes stratified random designs. Ocular estimates of standing volume may be used in place of sampling but there may be a trend towards defining stands and their attributes more precisely.*

Turner points out that existing stand inventory techniques are purpose-based and generally address the need of commercial forestry.

The private resource is fragmented and as such the current methodologies are not always applicable; one reason being cost.

Stand class mapping is generally being carried out in native forests using 1:25,000 scale aerial photography. Recent research, by NFI, suggests that the gross area of forest with commercial potential is at least 15 million hectares. To assess this area in the traditional manner, approximately \$15 million would be required for mapping plus an amount of similar order for field surveys.

New and more cost effective techniques for quantifying the forest resources are clearly needed.

The more significant points to come out of consultations with a wide cross-section of experts are as follows:

### **2.1.1 Tasmania**

As a result of a number of projects, including work under the Regional Forest Agreement, the public and private forest estate now has the most detailed native forest mapping in Australia. The forest estate has now been classified using 1:25,000 scale aerial photography to map forest type, based on stand density and height class. Species, products and volumes are generally determined by ground based strip assessments. These data, together with some interpretation of aerial photography to identify species, has been used to develop dominant floristics mapping that has been laid over Tasmania's forest type mapping using GIS.

The Tasmanian definition of "forest type" is not consistent with that defined in section 2.3 as it does not recognise species and/or understorey. Although of no consequence within the region, this will cause difficulties if the information is aggregated to the national level.

Private Forestry - Tasmania have addressed the issues of "owner objectives management intent" by conducting a survey of private native forest owners. All owners, excluding conservation and wildlife reserves and large industrial owners, were requested to provide information concerning the expected use of their forested land. The survey (1996) achieved approximately a 60 % response rate. The results of this survey were used to adjust the area available for timber production, adding to the discounts required under the State's forest practices code. The survey cost approximately \$20,000 but was considered cost effective as it gave information previously unavailable.

### **2.1.2 Victoria**

Resource inventory of privately managed forests is basically confined to the inventory of eucalypt and softwood plantations.

However, for Victoria, there is now a consistent mapping of forest cover across all tenure, using Landsat TM data and mapping onto a GIS database at 1:100,000 scale. This mapping has recently been improved to include overstorey species, stand height and canopy cover for eastern Victoria and dominant genus, stand height and canopy

cover for the north west of the state. Mapping is about to commence to map the overstorey species, stand height and canopy cover for the south west of the state. At this scale, however, the information will only be of use for regional and national level planning and will provide little value to the bulk of private owners.

Major plantation growers normally use standard remote sensing techniques (aerial photographs at 1:25,000 or larger scale) and GIS technology for mapping their resource. Typically they then apply a systematic field sampling procedure. Processing is done using in-house software packages.

Australian Paper Plantations Pty. Ltd., stratify their plantations into management units based on mean rainfall developed from the Bioclim model (Booth, 1990), soils, elevation and aspect. They recently contracted Greaves to conduct a review of "Current practices used in the inventory of temperate Eucalypt plantation in southern Australia and NZ". Unfortunately the report is currently unavailable.

Plantation management systems are generally deficient in providing information about yield by product quality classes. To address this, some organisations are currently considering or implementing the New Zealand - MARVL software package.

### **2.1.3 South Australia.**

The native forest in South Australia has been mapped at a scale of 1:100,000 (or better) through a number of projects. The State also has a large biological survey program, based on field plots, which has been used to sample and refine the regional mapping.

Resource inventory of privately managed forests is generally limited to plantations. The inventory procedures adopted closely follow that developed by the SA Government (Lewis et al 1976).

For radiata pine yield estimation and regulation is based on a volume based productivity index (Site Quality). For the initial inventory, plots are established at age 9.5 years and diameters and heights are measured to estimate stand volumes which are used to predict future yields. Subsequent strata, based on site quality, are then sampled using stratified random sampling. During inventory, trees to be extracted in the next commercial operation are demarcated to enable prediction to be made of thinning yields.

Australia wide adoption of this approach is doubtful because the complete set of field variables and related functions are generally not available in other areas. This makes it impossible to directly aggregate field inventory data across all regions. Hence national level processing of field data and aggregation of information is not feasible.

### **2.1.4 Queensland**

The Statewide Landcover and Trees (SLATS) project currently being undertaken by Queensland Department of Natural Resources aims to develop forest cover mapping

data for private and leasehold lands and to monitor changes in forest extent, condition and trends in Queensland's vegetation cover at regular intervals. The project is using Landsat TM remote sensing to assess the impacts of tree clearing and woodland regrowth on the greenhouse gas emission balance.

Other than this broad scale work, very little has been done concerning the resource inventory of private forests. However the CRA/RFA process for the South East of Queensland has applied or will apply the following methodology:

- An inventory of the standing volume of merchantable timber on private land.
- A modelling exercise to estimate the productivity of these areas of private land.
- A survey of land holder attitudes and intentions regarding areas of native forest on their properties.

The following notes summarise the details of the approach used.

*Inventory procedure.*

- Resource stratification.
  - Land tenure (freehold or leasehold where the Government does not have timber rights).
  - Property size, only properties greater than 20 hectares.
  - Regional Ecosystem Types (RETs) as the base stratification unit for forest type. RETs were used as a surrogate for forest types and were based on environmental domain modelling using extensive Department of Primary Industries – Forestry databases detailing dominant species. RETs were further grouped into six broad vegetation classes.
  - Forest patch size, only patches greater than 20 hectares.
  - Management history was also identified as an important variable affecting stand condition and volume, however little information was available on this.
- Sampling procedure.
  - RETs were randomly sampled at varying intensities depending on a subjective consideration of their importance to the timber industry.
  - Plots were located using GPS and topographic and satellite image maps.
  - If no forest was present then assessors would mark it as null or assess a patch of similar forest if in close proximity, presumably to determine potential.
  - Plots were visually assessed by experienced timber assessors and, due to accuracy issues, volumes were placed into volume classes only. Other factors recorded for each plot included disturbance by type and ground cover.
  - At least one plot in each RET was revisited and physically measured to obtain a measure of accuracy of the visual estimates.

*Productivity modelling.*

Extensive data sets exist that, when analysed, indicate productivity levels for public land, but little is known of productivity of private land. Environmental domain data covers all tenures and will be used to extrapolate productivity to private land by modelling the extensive DPI Forestry permanent plot data to estimated productivity of privately managed forests.

### *Landowner survey.*

Several extension officers with the Department of Primary Industry and the Department of Natural Resources were consulted to obtain an understanding of land holder's intentions towards the private forests on their lands. Further, a number of land holders were met and questioned concerning their intentions towards their native forest.

In addition, as part of a survey of managers and owners of sawmills in south-east Queensland, questions were asked on log supply, log quality and access issues from private forests.

A number of problems occurred during the implementation of this approach, which include;

- sampling was restricted to areas adjacent to roads, (presumably due to logistics and time constraints),
- management history was not included in the stratification,
- poor relationships were found between the visual and measured estimates of volume, and
- not enough account was taken of the regrowth areas and their productive capacity.

### **2.1.5 Western Australia.**

Recently through the Agricultural Land Cover Change (ALCC) and RFA process, extensive mapping of private forests has taken place, including the mapping of forest types and disturbance as part of reserve design target setting. Broad estimates of standing volumes of timber on private land have also been developed. A significant development of this work has been the development of procedures for mapping disturbance and forest condition (defined here as the amount of regeneration occurring in the forest based on disturbance regimes rather than forest growth) using Landsat TM data.

CALM do not undertake assessment of private native forests as, historically, they have contributed very little (less than 3% per annum in the south west) to the total hardwood supply, and this contribution is diminishing rapidly. One reason for this is that there are a range of constraints relating to land clearing and catchment management that restrict harvesting of these resources. Consequently, very little has been done concerning the inventory of this estate on a regional basis. Where inventory has occurred the methodology used has been based on the native forest inventory procedures developed for public forests.

CALM actively promote sharefarming in both pine and blue gum plantations. They perform a standard plantation inventory, which mainly involves aerial photography for site and stocking classification and the early establishment of growth monitoring plots to measure performance.

Bunnings Treefarms assess their plantations using stratified random sampling techniques and analyse the data through MARVL (modified with their own growth

and taper functions). Native forest inventory is opportunistic and is generally carried out prior to harvest using variable radius plots and product cruising techniques to determine yields by product type. Processing is through in-house systems.

### **2.1.6 New South Wales**

State wide mapping, completed in 1995 by the NFI using existing data sets and AVHRR satellite imagery, has recently been superseded by Landsat TM mapping of woody vegetation for the Basincare project. Now ALCC aims to complete the mapping of 1990 and 1995 forest cover in the first half of 1998. These data sets will provide information on the dominant genus, canopy cover, landcover and changes in these attributes between 1990 and 1995.

Prior to these studies, the only inventory of private forest was the FORINS study undertaken by State Forests in 1972 prior to the FORWOOD conference in 1974. The Statewide study was based on a systematic grid of "photo-plots" that were interpreted according to tenure, broad forest types and standing volume.

Since FORINS no significant wood resource inventories have been undertaken on private forests apart from one completed in 1994 for the Northern Rivers Development Board for areas within approximately 250km from Grafton, NSW. The aim of the study was to, determine the area of productive private forests and the expected yields from these forests taking account of species and site quality, and to identify constraints or impediments to private forestry. The study was undertaken using manual mapping techniques, with no spatial data capture. Forest area calculations and growth rates were based on local knowledge, standing volumes were calculated largely from visual estimates and extrapolation, and management intent was captured through land holder surveys.

Mapping at 1:25,000 scale using aerial photographs is currently being undertaken within RFA regions. However, due to limitations of budget and time only broad floristics, and structural information relevant to old growth assessments are being mapped. Further, this does not cater for the native forests in the west of the State.

The Bureau of Resource Sciences is currently scoping other methods for estimating current and future wood resources for these regions.

### **2.1.7 Summary Comments**

Privately managed plantations have generally been assessed using well-developed methodologies albeit limited to production and operational purposes. These methodologies appear adequate for the larger organisations and/or cooperatives but are proving expensive to maintain. They are expensive for small owners.

A number of projects have recently been initiated to map private land into broad productivity classes for plantation development. For example, private land in NE Victoria has recently been mapped into broad productivity classes for plantation

establishment. The process involves the correlation of MAI figures from existing softwood plantations with soils and rainfall information. The work is being carried out at 1:250,000 scale and is currently being extended to other regions of the State. This scale is far from satisfactory and research is needed to develop a more consistent but inexpensive approach to productivity mapping for plantation development.

Very little inventory of privately managed native forests is carried out. Generally, broad scale (1:100,000) forest cover information has been captured but this is only of use at the regional and national levels. Some area data are available for production forests, as are some volume estimates. Inventories are fragmented, inconsistent, and limited in their use (especially at the operational level).

The methodologies of most use in future work are those developed for the CRA/RFA process in South East Queensland and the land holder survey used in Tasmania.

## ***2.2 Data processing for private forests.***

The general lack of supported inventory processing systems and software, suitable for small and medium forest growers was noticeable.

Many of the larger companies have invested in proprietary or in-house systems. However, the skill base to maintain and further develop these systems is diminishing. Some organisations are adapting overseas software at considerable expense (eg MARVL from Forest Research Institute - New Zealand).

Owners of smaller properties have neither the incentives nor the resources to invest in such a process. However, some forest consultants do offer a service to process simple inventory data for farm forests.

## **3. Evaluation and review of current practices.**

The current situation is summarised in a paper by Brack (1997). Brack points out that Australian forest services have tended to continue to use the sampling technologies first adopted during the 1940's. Despite this, they have implemented increasingly powerful technologies to improve the efficiency of sampling. Such technologies include better air photo resolution, colour photos, and remote sensing with more wavelengths and better resolution.

Except for the inventory of private native forests of South East Queensland, the objectives of inventory of privately managed forests have been primarily to determine volume estimates of products from an imminent harvesting operation. As such the inventories do not provide information that can be aggregated to the regional level as they are of variable design and standards.

Most inventories of smaller private native forests are undertaken on commission by their owners, their intent being to harvest for timber products and harvesting often happens as a consequence of some other decision. Such inventories are biased

towards the intent to harvest and the products that are currently marketable. An inventory that produces more generic resources estimates is needed.

Existing processing and database systems are generally purpose-built to address the needs of the organisation concerned. Further, source inventory data are often stored in a format and processed in idiosyncratic ways. Extraction of this data for regional planning, would require additional processing to derive information compatible with regional categories. This would invariably involve intervention and interpretation which, is a costly exercise and may compromise the integrity of regional data.

In WA a concern that privately managed native forests currently will contribute little to regional sustainable yields is widespread. While this assumption may hold for timber production it doesn't necessarily hold for other forest uses and forest values.

Further, current management of private native forests is opportunistic with respect to timber production. If the markets were available and/or timber production was promoted to owners they would manage their forests for timber. The concern is that current inventory data may be biased towards management intent for timber production.

#### **4. Management Objectives and Intentions**

The management objectives and intentions of privately managed forests varies considerably. The size of the organisation, the nature of the resource, and the objectives of the owner, can all have a marked affect on whether or not the resource contributes to sustainable forest management (SFM).

More specifically the factors involved include the following.

- Organisational differences, especially for larger industrial owners. These basically come about due to historical reasons. For example, South Australian and Victorian plantation growers, although managing what could be considered essentially the same type of resource, have developed entirely different inventory and data management approaches for very logical and pragmatic reasons. Changing the approach would not be appropriate due to organisational work practices that have been established.
- Owners objectives. Objectives include, timber production, non-timber production, conservation and the objectives may be intensive or extensive.

A clear statement of objectives is fundamental to all inventories. If an objective is to intensively manage the forest for timber production, then detailed knowledge of the resource and its potential growth is required. On the other hand if the intent is to clear the land for agriculture, only a pre-harvest inventory need be applied.

Conversely, if the intent is to do nothing, the owner may not be interested in collecting any inventory data at all and generally would not be prepared to contribute funding to the inventory. Further, they may, in some cases, even resent and resist any governing body assessing the resource even if the assessment was for regional planning.

However, in all cases, some knowledge is required to address national and regional sustainable forest management issues. This issue will have to be addressed if the protocol is to be implemented, and is a serious concern.

- Government regulations. For example, in Western Australia owners cannot manage their native forests for timber production in some catchments, but they can utilise timber if they clear land for “normal” agricultural purposes. Paradoxically, they cannot clear native forest to establish a plantation.
- Economies of scale. The question here is, does the resource support economies of scale for a single owner to significantly impact the regional picture? The answer to this question depends on a number of factors including owners’ objectives and intentions, the size of the resource, the proximity to neighbouring resources and the proximity to a market.
- Fragmentation. The private resource is fragmented making it difficult to educate and assist owners. A level of distrust often prevails. The owner’s objectives may conflict with regional planning which may be seen as unnecessary interference by some.

The issues are complex and will require further careful study.

## **5. Common Elements to Future Inventory Design**

The approach to be taken on privately managed forests differs somewhat for native forests versus plantations because of the greater complexity of product classes in native forests, especially with respect to defect, and the need for additional information on species composition and structure. Nevertheless, there are common or potentially common areas. Thus before examining the defining differences, it is appropriate to deal with the general issues of the changing context of inventory information, maintaining regional and national data, and inventory design.

### ***5.1 The changing context of inventory information***

One major issue underpins both native forests and plantations- the need for data to be treated in confidence, and hence without identification of the owner or the potential to do so.

This issue may seem to contradict some of the present practices in which some owners, especially State plantation enterprises and large private owners, have quite generously made their complete inventory information available. However, the thrust of the Australian Competition Policy will soon render this impracticable because potentially in that form it could provide other competitors with access to commercially sensitive information and thus undermine the pursuit of commercial competition between and among private and public owners. The present distinction in private versus public ownership of plantations is also not a meaningful one in the long run because of the impact of the trend to corporatisation and privatisation and the attendant greater emphasis on commercial confidentiality.

It is unclear whether the impact of the Australian Competition Policy will ultimately extend to inventory data from publicly owned native forests. The requirements for transparency of the process of determining sustainable yields for timber and other wood products suggests that these data may remain in the public domain. If, on the other hand, management agencies are corporatised and pursue more detailed inventories for commercial purposes, access to that data may be restricted. Under these circumstances, it is possible that separate inventories need to be used for regulatory versus management purposes by the respective agencies concerned.

Whatever the approach taken in designing inventory for privately managed forests, it must take account of the impact of these changes. They may not be pressing issues now but it is clear that they will become so over the next decade. Innovation therefore needs to be matched with the future context.

## **5.2 *Maintaining regional and national data***

There is also the issue of maintaining the various data sets. Information created from source data and aggregated to the regional and national level will need management to address the following matters. Such management will incur significant funding.

- Confidentiality and security. All data from private owners must be held confidentially. Any information published must be in an aggregated form by categories and/or localities so that information about any one ownership cannot be traced. This also requires strict access procedures to be implemented for all data and information other than the published aggregates.
- Integrity and Updating. All data should be stored with a “use-by-date” after which it should be archived. This necessitates that data and information be clearly annotated with respect to this date and with some estimate of precision and bias. This could be 5 to 10 years for native forests and 1 to 3 years for plantations.
- Quality control. This is linked to the integrity of the data. Responsibility for quality of both the conduct of inventory itself and of any resultant data must rest with the organisation responsible for the inventory. Some checking by regions may be needed to provide appropriate assurance. There may be a role for regional organisations, such as the Regional Plantation Committees, to pursue quality control activities, thereby providing some regional feedback to the owners concerned to assist in improving inventory practices.

## **5.3 *Inventory design***

Although a variety of tools and methods can be used to collect data, systematic and consistent storage of the resulting aggregate information with appropriate indices of precision and scale is needed to provide a uniform approach. A multi-level approach should be adopted based on minimum sampling levels considered acceptable for different categories of forest type (native forest versus plantation) and ownership.

### **5.3.1 Area classification**

There is the need, for the entire Australian forest estate, to accumulate both spatial and non-spatial data across similar forest types and across owners that have similar forest management objectives and intent within the forest types. The following grouping of areas is suggested.

- Vegetative cover categorised into forest or non-forest land.
- Forest land would be further categorised by forest type and condition.
- Broad tenure, (for example, public and private)
- Privately managed forest categorised into freehold and leasehold, industrial or non industrial, and size classes.
- Long term management objective of the owner categorised into commercial (for example; timber and/or non timber), conservation, or no objectives
- Short term (say 5 years) management intent categorised into harvesting planned, harvesting not planned.

### **5.3.2 Spatial data**

Spatial data can be collected by satellite imagery (eg AVHRR), thematic mapping, aerial photography and/or ground survey). Due to the varying nature of the resource, a multi stage process is recommended with a corresponding variety of levels of precision prescribed.

The minimum expected precision would need to be defined for each of a series of forest type, ownership, and management intent categories. These must aim to meet the needs of different levels of planners at the national and regional levels as well as those of the owners. Recording the source and precision of spatial data as well as attribute data is essential.

Research is needed to determine the best method of defining spatial precision and bias, how should these be measured, and what levels should be prescribed.

GIS is the obvious tool for spatial data management however research is required to define the minimum standards that are required for data entry at various scales.

### **5.3.3 Attribute data collection**

There are a number of options for the cost- effective collection of attribute data. These options include statistically-based sample and design-based systems, as well as non-statistically-based methods of data collection.

Because no single system will meet all situations, there is a need to be able to re-compile the aggregate information from a number of sources and to use several approaches to estimate resource levels. Where estimates from different approaches conflict, the information system must be able to resolve or harmonise the discrepancies using either statistically valid techniques, or robust and defensible

heuristic's (Brack 1997). Where information is poor, it may be necessary to collect additional data to upgrade the precision or reliability of the information. In this event, the choice of a cost-effective collection technique is critical.

For a more detailed discussion of the various mensurational practices and sampling systems that follow consult standard text books or visit Dr C. Brack's web site (<http://www.anu.edu.au/Forestry/mensuration/MENSHOME.htm>).

Where little ground-based inventory is possible, but GIS or spatial (eg. climatic) models are available, the spatial models can be used to predict the orders-of-magnitude for each hectare block of forest. The resultant list can be used in a variable probability sampling system in the list sampling of a small number of samples, say of 1 hectare, selected and measured to provide a relatively precise estimate of regional total volumes. Land holder anonymity can be maintained by restricting that data processing to aggregate estimates.

Where several individual owners are interested in inventory of their forests, but there is no pre-existing remote sensing or aerial photo interpretation, then each land holder could implement an efficient inventory of 'n' point-samples with perhaps 'm' centroid samples. The point samples can be established at systematic locations using either simple or sophisticated mensuration depending on the precision required and skills of the inventory crews. Instructions for the establishment and processing are available (and simple spreadsheet programs or tables can be used for estimating volumes and other information). A set of instructions for modified point list sampling with centroid sampling has been published on the world wide web by Dr C. Brack at (<http://www.anu.edu.au/Forestry/mensuration/MENSHOME.htm>) and only needs a set of tables and a hand calculator for processing.

Where little is known of certain forests and the owners are not supportive of carrying out a new inventory, then one approach would be to develop a "plausible model" to predict volumes, (using available dependent parameters). A range of stands, where sampling has or can be carried out and which cover the range of dependent parameters in the plausible model, would be assessed and the resulting data used to 'fit' the plausible model and estimate coefficients. The root mean square error of the regression model can be used to estimate the reliability of the subsequent model-based estimates of average and totals.

Where data and information are lacking but the potential volumes important, a multi-stage approach using remote sensing for stratification and airborne video images and laser for 2-D and 3-D "photo-plot" establishment may be the most cost-effective solution

As previously noted the objectives for this study do not encompass the issue of estimating productivity and growth except where it is inferred under "condition". This issue needs to be addressed in depth. Similarly growth, mortality and product yield models need considerable research. Hybrid modelling, which uses a mixture of empirical modelling and physiological or process modelling techniques, probably offers the best chance of success. The exact balance between these two modelling components will vary between users and uses. Remeasured inventory plots are

unlikely to be able to provide the necessary growth information to support such modelling and it will be necessary to review the other various sets of permanent plots that have been established to determine forest growth.

#### **5.3.3.1 *Sampling with equal probability of plot selection***

Equal probability sampling systems are the most commonly used sampling systems in natural resource inventories. These methodologies include “simple random”, “strip line” and “systematic” sampling and have been in use for considerable time.

Equal probability sampling is relatively easy to understand and inventories can be easily and cheaply designed. The data collected can be analysed by anybody with a rudimentary understanding of statistics. However, equal probability sampling systems are often relatively inefficient, having a low precision for a given number of samples. Consequently, this form of sampling may be inappropriate when attempting to provide precise estimates of the mean of total volumes of a variable resource over an extensive area within a tight budget.

Stratified random sampling uses equal probability sampling within homogenous strata. If the strata are well determined *a priori*, using existing maps of species type etc. then the efficiency of the overall inventory can be greatly increased. However, an increasingly common approach is to determine the areas of the strata *post priori*, based on the results of a systematic sample of points. This does not give the same improvement in precision of the aggregate volume, being identical to that for simple random or systematic sampling described earlier. Stratification after sampling means that the estimate of the area of each stratum is also a random variable with an (unknown) variance, which is often ignored in subsequent analysis.

#### **5.3.3.2 *Sampling with unequal probability of plot selection***

Unequal probability sampling, also called variable probability or probability proportional to size, provides statistically valid sampling systems that are more efficient than equal probability systems. The most common unequal probability sampling system used in forestry is the *angle count sampling* method of determining stand basal area or volume.

Unequal probability sampling concentrates measurements on the “more important” sample elements in the population by selecting elements proportionally to their size. Thus, for example, a tree with a large dbhob will have a greater probability of being selected in a sample, which is designed to estimate basal area or volume in a stand.

Unequal probability sampling can be used to select individual trees in a stand, or stands within in forest. For example, if a list of predicted volumes for each stand in a forest were available (that could include estimates provided by a foreman or by a computer simulation), then a small number of these stands could be selected for intensive measurement. If the selection probability were proportional to the predicted volume of the stand, then the total volume of the forest could be estimated with

greater precision than if the same number of stands were selected with equal probability.

Processing data collected with unequal probability is reasonably simple although the underlying concepts of the method are not widely understood. Another disadvantage of this approach is that while the nominated variable is estimated with increased precision, other variables may be determined with poorer precision. For example, angle gauge samples will estimate stand basal area with greater precision than is commonly achievable with equal probability sample plots, but the estimates of stocking are poorer in precision than the equivalent plot based estimates.

#### **5.3.3.3 *Model-based estimates***

Model-based estimation procedures attempt to provide predictive models from easily measured or understood variables. The form of these models may be determined from theoretical (process-based) understanding or passive observation (statistically based). The models may be calibrated or fitted against test data which, may or may not be selected on a probability basis. In principle, it is possible to conduct independent tests to provide estimates of precision of these models, although obtaining the data may be so costly as to rule this out. Failing independent tests of precision, statistics such as the root mean square error provide some gauge of precision.

Yield functions that use age as an independent variable to predict the volume of a stand at any age are a common example of model-based estimation used in forestry. Sophisticated models have been developed to predict the standing volume of a forest given a range of environmental and allocation data. The ongoing State-wide Forest Resource Inventory (SFRI) project in Victoria assumed that an underlying model can be developed relating current standing volume to variables that can be observed from aerial photographs and environmental or terrain data that can be estimated from geographical information systems by spatial modelling. Sample points were selected to calibrate the underlying model and quantify the model coefficients. The method lacks measurement of the forest variables and one would expect an estimate based on yield function estimates for various sampling points to be far less precise than one based on plot measurements at those points.

#### **5.3.3.4 *Non-statistically-based systems***

Non-statistically-based systems involve subjective and *ad hoc* sampling. It is very difficult to determine the reliability of these types of samples and they should be avoided if at all possible.

Experienced foresters and forest workers may be able to “ocularly estimate” the volume and other parameters of importance in a forest. This experience and knowledge has been used to good effect in some places (Brack 1997) but experience in other organisations has been much less encouraging. The main requirement for effective information collection is the existence of a body of workers with sufficient experience and knowledge to reliably estimate timber resources on small areas, and sufficient time to visit all the small forest areas that could be surveyed as a whole from

one spot. Unfortunately the precision and freedom from bias of the purely ocular estimate is difficult and expensive to quantify. If ocular estimates are used, good documentation is essential.

#### **5.3.4 Multi-stage inventories**

Many of the above methodologies can be combined in a multi-stage sampling approach. The multi-stage process involves the subdivision of the forest into primary sampling units. These units are then randomly selected for further subdivision into secondary sampling units which then may be randomly selected for a third subdivision and so on.

Different technologies for sampling can be employed at each stage, for example the interpretation of strata from aerial photography data is particularly useful for grouping relatively homogeneous areas, as a precursor to stratified random sampling. More complex forms may involve initial stratification from satellite imagery, followed by sub-sampling by aerial photography or airborne video, and a third sub-sampling by field plots. Further, in a comparison of inventory designs for the estimation of yield from pine plantations, it was found that model based inventories using a Spiegel Relaskop on variable radius plots were quicker and cheaper to implement because the assessment of products was restricted to a small sub-sample of trees (Biggs 1990).

Multi-stage sampling has the advantage of concentrating work on specific samples of interest. The technique is particularly useful where primary sampling units vary in importance (for the parameter/s being estimated) and allows further sampling to be concentrated in areas of greater significance with respect to the parameters. The choice of technology and sampling intensity at each stage is related to available funds, scale and management intent.

## **6. Data Processing and Implementation**

### **6.1 Data processing**

Plot and other measured data needs to be analysed to meet the needs of individual owners and also to provide information for aggregation to both the regional and national level. A simple, easy to use system that takes a variety of plot data as input and calculates the appropriate information needs to be developed. This would have the added advantage of providing a set of protocols that would yield consistent information for aggregation at the regional and national levels.

The system could either be supplied to owners for their own use or could be offered as a bureau service. If the latter is implemented, only processed information would be stored and made available at appropriate levels of aggregation.

The system would only incorporate short-term growth models, enabling all data within a prescribed time frame to be updated to estimates for the desired base year. However, it would not include long term modelling and yield planning.

## **6.2 Implementation**

Education and promotion of regional inventories of privately managed forests is of paramount importance, again this would involve funding and time. One way to minimise the costs would be to encourage grower cooperatives to promote this work. The reasons and advantages need to be carefully spelt out to give the various owners reasons to consider and undertake the management of their forested land.

The purchase of region-wide remote sensing data through the NFI and/or Regional Plantation Committees offers a means of providing these data more cheaply to private owners than the total cost of individual purchases.

## **7. Differentiating between Native Forests and Plantations**

The differences between native forests and plantations are such that they demand different approaches.

### **7.1 Privately managed native forests**

The key issue with these forests is that they tend to be small estates that are widely dispersed spatially and in ownership, and highly variable in species, structures, and present and future commercial productivity. While some estates in Queensland, Northern Territory, New South Wales, and to some extent Tasmania, may be quite large in terms of average area, especially where private leasehold is involved, the preceding comments still hold in a *relative* sense for all States.

Inventory data are generally only available for a few (at most) major estates in each State or Territory. Because of the differing species, structures and utilisation standards, the highly variable and sometimes very imprecise and potentially biased inventory estimates, aggregation and re-working of these estimates is neither a sensible nor a feasible option. In any event, the overwhelming majority of private managers of native forest estates do not carry out inventories worthy of the name. Instead they rely on ocular estimates or at best rudimentary and subjective surveys.

If regional inventories are to be carried out for NFI or RFA purposes, or regional planning, an objective sampling design is needed to provide an unbiased estimate of the forest types, structures, and volumes.

Any field sampling will need to be of relatively low intensity to be economically commensurate with the importance of this resource. The adoption of multi-stage inventories such as those used in Western Australian public forests needs to be pursued to assist in achieving adequate precision at reasonable cost. (Biggs and Spencer 1990). The design of the inventory used two phase sampling. The first phase

involving intensive systematic large scale aerial photographs (1:2,000) to obtain gross bole volume estimates. The second phase involved re-sampling 10 % of the first phase plots on the ground to correct any bias in photo-estimates and to obtain detailed information for partitioning the gross bole volumes into product classes of various types. The application of the technique may not be applicable in dense forests where photo measurements would be difficult. However the benefits, the speed with which the samples can be obtained and the lower overall cost, may be significant.

Standard protocols need to be developed for field sampling. This is not to say that total uniformity is required of the plot sizes used and measurements taken in field sampling but standard goals must be set for the statistics to be provided from the field sampling to develop estimates of (gross bole) volumes. Standard field sampling approaches need to be used to estimate defect and hence estimates of merchantable volumes and assortments.

This approach presents new challenges for research in forest inventory but ones that can be readily and fairly quickly addressed. Once complete, some owners of larger estates may be encouraged to adopt these protocols to reduce the burden of field sampling. If so, the procedures outlined below for privately managed plantations need to be adopted to maintain confidentiality and security of the data.

## **7.2 Privately managed plantations**

The situation with plantations is markedly different in that the bulk of the plantation estate, especially of softwood, is in large estates with relatively few owners.

Intensive inventories of the larger plantation estates are carried out by a majority of owners. However, two problems arise in attempting to utilise this information in a national or regional inventory of the privately managed resource.

The first relates to the confidentiality and security of the data. This will become an increasingly serious and acute issue due to the Australian Competition Policy. Presently, State-owned plantations have to be treated as if privately owned with attendant implications of commercial-in-confidence data.

The second concerns the varying protocols used in estimating volumes and future yields from the basic data and the varying (in time as well as place) standards used to define various log products.

Research is required to review field data collected by the larger plantation owners and to develop a process of sub-sampling of that data that preserves their confidentiality and security and at the same time enables a standard approach to measurement protocols and utilisation standards. Actual field sampling could then be confined to the stratum comprised of small plantation estates for which no useable data have been collected by their owners or managers

Aggregate plantation areas (generally including species) information can be obtained through remote sensing including both satellite imagery and aerial photography. This

should provide a precise sampling frame, which can be maintained on a GIS database. The NFI is well equipped to assist the States in this endeavour.

The principal difficulty is that almost all inventory of plantations stratifies initially on the basis of age. It should be possible to pursue these data for new plantings from remote sensing data. However, the provision of data for existing age classes may require the co-operation of the large owners but this need not necessarily require the cadastral boundaries to be available.

The solution to the differing standards of measurement protocols and utilisation used by larger plantation owners is to define the minimum critical set of basic statistics collected by and readily estimated from the field data. Age and tree diameter at breast height need no elaboration. Stand height does, as slightly different definitions are used in different regions and States. Nevertheless, conversion of one measure to another can be fairly precisely accomplished and hence the basic statistics are useful. From such a set, it would be possible to develop predictive equations that estimate a standard set of assortment volumes, using uniform definitions of those assortments and appropriate collection of data to estimate the functions concerned. Such a process is preferable to the aggregation of assortment volumes for individual species that reflect different definitions because this introduces biases that are unknown and uncontrollable. It would also assist in preserving the confidentiality of the data, since the assortment definitions and predictive functions adopted by each owner need not be known or used.

Where, as is now often the case, the plantation inventory is based on a succession of inventories over, say, the last five years using temporary plots whose statistics are updated to the present using predictive growth functions, similar measures would have to be adopted using uniform predictive equations for the species and regions concerned.

Another solution to ensure confidentiality is to restrict any use of owner-developed data to a random sub-sample of the total set for an age class. The proportion to be taken in the sub-sample needs further investigation but one third might be adequate in general, although modification might be needed for estates with low sampling intensity. The details of the approach need further research especially to ensure that the two data sets both gave consistent estimates. Where an owner used a stratified sampling within an age class, the sub-sample could be based on a random sample that reflects the proportional area of the strata in the estate, so that the sub-sample is equivalent to a random sample of the estate. All specific ownership identification would be removed, other than any general classification of size of estate, species and the like. This should, if required, be carried out by an independent organisation with suitable skills on a contract basis and bound by confidentiality provisions, with the resulting data files being supplied to the NFI for final processing as an anonymous and thus confidential aggregate of data. The contractor might also have to determine whether the base inventory meets the specified minimum criteria for objective sampling,

Field sampling of smaller estates would be needed to complete the inventory but this would not be extensive or unduly expensive.

The work involved in this approach is substantial and may initially be less preferable than the current approach of gaining complete access to large owner data and aggregating it. Leaving aside the technical defects of the present process due to different standards, the salient point is that it will not be viable in the long run. It would therefore be better to initiate change to a more viable system now.

## **8. Recommendations and Research Needs**

1. The objectives for this study do not encompass the issue of estimating productivity and growth. This issue needs to be addressed in depth. Productivity, an indicator of growth potential, is usually calculated from a number of measurable parameters and its definition, determination and subsequent consistent mapping depend on a whole range of site and stand characteristics such as soils, species, past treatments.

Remeasured inventory plots are unlikely to be able to provide the necessary growth information to support such modelling and it will be necessary to review the other various sets of permanent plots that have been established to determine forest growth.

### *Recommendation:*

It is strongly recommended that a separate study be initiated to investigate the issues of growth and productivity.

2. There are significant differences between plantations and native forests with respect to the size and nature of the resource, owners' objectives and management intent.

Plantation inventory (by its nature, is intensive) is aimed at the provision of information to estimate yield for harvesting operation in both the short and long term. Existing methodologies have generally been developed by large companies with economy of scale and/or modified from government developed methodologies. The information provided from them generally can be readily aggregated to provide regional and nation level information for sustainable forest management and planning.

However, the methodologies currently used by larger plantation owners are labour dependant and labour intensive; and are becoming more expensive as wages costs increase. In addition, the processing systems used in conjunction with the inventories are complex, and the skills base required to maintain these systems is diminishing. New technologies need to be developed, and economies of scale for development promoted, in order to achieve efficiency gains.

The situation is quite different concerning the privately managed native forests. Inventories have either been opportunistic with fixed objectives in mind, been of such a broad scale they mean little to the owner, or in some cases simply have not

been done and parameters have merely been estimated. Aggregation of information from such a mix of methodologies is difficult at best and would need to be used vary carefully for regional and national sustainable forest management. Precision would be unknown.

Whatever the differences between plantations and native forests, a protocol needs to be developed that allows the application of a variety of technologies for the collection and aggregation of forest resources data. The adoption of a multi-stage approach should be explored as different but appropriate technologies for sampling could be employed at each stage and it has the advantage of concentrating work on specific samples of interest. The choice of technology and sampling intensity at each stage needs to be related to available funds, scale and management intent.

Such a protocol could also be applied to government managed forest, especially to reserves, where less is known about the nature of the total resource.

#### *Recommendations:*

It is recommended that a protocol be developed to facilitate the collection of standard resources data for different resource categories and different management planning levels to provide:

- At the operational level, sufficient detail as required by the owner and can be processed to provide data compatible with regional sustainable forest management requirements, and,
- At the regional or at a broader scale level, consistent information for regional sustainable forest management.

It is further recommended that a pilot study be conducted to build on the findings of this study and more thoroughly design a mapping and sampling framework for operational, regional and national inventory. Thus priorities to implement the following research needs could more easily be established depending on requirements by different agencies and source of funding.

### **8.1 Research Needs**

The following research needs have been identified but are not in any order of priority because different aspects are likely to be funded and carried out by different agencies.

1. More efficient and cost effective methods for stand stratification are needed. Remote sensing technologies offer considerable scope but the following issues needs to be addressed
  - Remote sensing and GIS technologies need to be integrated fully into planning,
  - No single remote sensing platform is capable of resolving inventory requirements (FWPRDC Application of Remote Sensing to Forestry study), and thus greater attention needs to be given to combining these technologies

with other methods of stand stratification, including the possible integration with environmental data such as terrain, climate and soils, and,

- The use of radar technology to gather cloud-free imagery for forest mapping.
2. Given the fragmented nature of the private resource, research is needed to investigate the use of new forms of remote sensing to supplement and/or replace data that has traditionally been collected by field sampling. Technologies such as the use of digital frame cameras, digital video, laser profiling and differential global positioning systems, all offer considerable scope.
  3. Reporting of the errors of estimates and the level of accuracy (or precision) needs to be standardised, both for spatial and attribute information.
  4. Research is needed into the mapping of forest communities, especially for biodiversity management.
  5. At the operational level, there is a need for product quality information. Research is needed to improve the efficiency of attaining product and product quality estimates.
  6. Field sampling techniques should continue to be developed and tested, including continuation of the development of p-3P and centroid sampling.
  7. The design of surveys to ascertain owners' objectives and management intents needs research. These are social surveys and need sociological input.
  8. Research is needed to develop generic growth models. The availability of data and the balance between different modelling techniques in order to meet completely different objectives needs to be considered in selecting appropriate models for different regions.
  9. A consistent approach to mapping plantation productivity is highly desirable at least on a region by region basis.
  10. Local cooperatives need to urge owners (in particular owners of smaller forest estates) to undertake more intensive inventory and management of their forest.

Apart from these research needs there are serious concerns about computing technology.

Computer system development is expensive. Are there better ways of minimising this through collaborative development? There is little available for use by the small private owner. Many larger private owners are using "out-of-date" systems because of the cost of updating and nothing readily available "off-the-shelf".

Thus, there is a need for;

- A generic base level system that can provide all forest owners and managers with a method of calculating inventory and providing the generic processed information that is required at regional/national level, and,
- A system to manage the processed information across all forested land areas.

This will require substantial funding but would provide information currently not available for regional sustainable forest management and planning.

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# Appendix I

## Montreal Criteria and Indicators considered relevant to this study.

The following are extracted from “Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests – The Montreal Process. 1995.

### **Criterion 1: Conservation of biological diversity**

*Ecosystem diversity,*

- a) Extent of area by forest type relative to total forest area.
- b) Extent of area by forest type and by age class or successional age.

### **Criterion 2: Maintenance of productive capacity for forest ecosystems**

- a) Area of forest land and net area of forest land available for timber production
- b) Total growing stock of both merchantable and non-merchantable trees species on forest land available for timber production.
- c) The area and growing stock of plantations of native and exotic species
- d) Annual removal of wood products compared to the volume determined to be sustainable.

### **Criterion 3: Maintenance of forest ecosystem health and vitality**

- a) Area and percent of forest affected by processes or agents beyond the range of historic variation, eg by insect, disease, competition from exotic species, fire, storm, land clearance, permanent flooding, salinisation, and domestic animals.
- b) Area and percent of forested land with diminished biological components indicative of changes in fundamental ecological processes (e.g. soil nutrient cycling, seed dispersion, pollination) and/or ecological continuity (monitoring of functionality important species such as fungi, arboreal epiphytes, nematodes, beetles, wasps, etc.)

### **Criterion 4: Conservation and maintenance of soil and water resources**

- a) Area and percent of forest land managed primarily for protective functions, e.g. watersheds, flood protection, avalanche protection, riparian zones

### **Criterion 5: Maintenance of forest contribution to global carbon cycles.**

- a) Total forest ecosystem biomass and carbon pool, and if appropriate, by forest type, age class, and successional stages.
- b) Contribution of forest ecosystems to the total global carbon budget, including absorption and release of carbon (standing biomass, coarse woody debris, peat and soil carbon).

### **Criterion 7: Legal, Institutional and economic framework for forest conservation and sustainable management.**

*Measure and Monitor*

- a) Scope, frequency and statistical reliability of forest inventories, assessments, monitoring and other relevant information.

## Appendix II

### Consultation

The subject of this scoping study was discussed with the following experts representing a range of organisations around Australia. The assistance and willingness to be involved of the various persons and their organisations is gratefully acknowledged.

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