forestworks ISC
INDUSTRY SKILLS COUNCIL
FOREST, WOOD, PAPER & TIMBER PRODUCTS INDUSTRY

Learning Resource for MANAGE SUSTAINABLE TREE INVENTORY








ICONS

Activities and assessments are interactive – the blank boxes can be filled in with your own information.

Activity

Assessment

This Learning Resource has been developed to support ***FPI60111 Advanced Diploma of Forest Industry Sustainability***. It was based on the Unit of Competency ***FPIFGM6203 Manage sustainable tree inventory***.

The project, managed by the Institute of Foresters of Australia, has been funded by ForestWorks with support from the Australian Government Department of Industry. Intellectual property remains with the Commonwealth and is freely available for educational purposes.

June 2014

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INTRODUCTION

ABOUT YOURSELF

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USING WEBSITE LINKS

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If you are consistently unable to access a link, please search for an alternative. If the link related to an assessment or activity include the new link in your answers. Let us know of any links that do not work by completing the feedback form at the back of the resource.

HOW ARE THESE MATERIALS USED?

This learning resource has been developed as a workbook with a strong focus on the self-directed application of knowledge. It is best used in the context of the Unit of Competency it has been written against as found on page 2. Completing this workbook and all activities and formative assessments will prepare you for your final assessment.

Where a table has been provided in activities and assessments you can use Adobe forms to make notes. Click on a cell to enter text, tab to move to the next cell. The table cells do not expand as you enter text.

When viewing the text online please turn on Bookmarks in your PDF reader so you can more easily navigate through the material.

SELF-ASSESSMENT

At the end of this document there is a self-assessment checklist of the types of skills and knowledge you would be expected to have to be deemed competent in the associated Unit of Competency. At any stage you can self-assess yourself against this list and seek more information in areas you are unsure about.

On successful completion of the final assessment as agreed with your Registered Training Organisation (RTO), you can achieve competency in the related Unit of Competency.

WHAT IS THIS LEARNING RESOURCE ABOUT?

This learning resource supports achievement of a unit of competency from the Advanced Diploma of Forest Industry Sustainability. The resource assumes that people working through it have been or are currently employed in a relevant field or in the tree growing and forest management part of a forestry or forest products organisation. It is designed to help those people to design, develop and manage inventory projects that gather primary data and information about the forests they manage.

The forests that are the subject of the inventory project might be native forests or plantations, and could be on public or private land. The data and information gathered would usually include forest location, extent and density. It might also cover attributes such as tree size (heights and diameters), other flora and fauna and wood product categories (for example, various grades of sawlogs, veneer logs and pulpwood).

The scope of this learning resource includes:

- conducting risk assessment to ensure that applicable workplace work health and safety requirements are applied to inventory projects in forests and plantations
- identifying the nature of the forests and plantations and site characteristics that should be considered when planning an inventory project
- developing an inventory plan by considering sampling strategy, forest stratification, technology and other factors
- managing the implementation of the inventory plan by using project management techniques
- reviewing the outcomes of the inventory plan to ensure that opportunities for improvement in further inventor projects are identified and can be realised.

To use this learning resource effectively, it would be useful to apply the activities specified to an inventory project relevant to your workplace. That project should be to prepare an inventory plan for an area of native forest or plantation that your organisation manages. A native state forest management block, a management block of a large plantation estate, a separate private plantation or native forest property would be suitable. The forest that is the subject of the inventory should be accessible to you and information about it should be available to draw on when you are working on the activities.

EMPLOYABILITY SKILLS

The learning resources for the Advanced Diploma of Forest Industry Sustainability are designed to help you draw from your work and life experiences to develop and apply skills that will enhance your employability in the forestry and wood products industries. Each learning resource addresses skills in particular functions that you might be required to undertake during a career in these industries. These functions range from the basic financial and workplace management skills common to a range of industries to sustainability and technical skills specific to the forestry and wood products industries.

When completing your daily work tasks and when working through each learning resource and the activities prescribed in them, you will be continually building on and demonstrating competency in generic skills, such as:

- analytical skills
- oral and written communication skills
- management skills
- teamwork skills
- technological skills
- numerical and mathematical skills.

HOW THE SKILLS LEARNED APPLY TO YOUR WORKPLACE

Forest management and forest products organisations and businesses use information and data gathered by inventory projects for a range of purposes, including:

- providing data and information about forest type, structure1, and other attributes
- short term operational and planning requirements
- medium term requirements, most commonly to estimate current tree product volumes
- longer term requirements, most importantly to determine growth rates and develop estate models to forecast potential future forest growth, wood supply and carbon sequestered.

Inventory projects are therefore usually a core and on-going function of forest management, whether the forest is managed for nature conservation, multiple-uses including timber production, or primarily for timber production.

1. CONDUCT RISK ASSESSMENT

This part of the learning resource addresses basic pre-requisites that must be considered before you can begin to plan the technical aspects of a tree inventory project:

- identifying applicable health and safety, environmental, legislative and organisational requirements relevant to managing a tree inventory project for sustainable tree management
- identifying the nature of resource and site characteristics of the forest area to be inventoried
- identifying enterprise requirements and enterprise outputs from the inventory project
- assessing and researching external influences that might affect the inventory project
- Identifying risks and potential outcomes that must be considered when planning and undertaking the inventory project.

IDENTIFY APPLICABLE LEGISLATION AND REGULATION

In Australia there are hundreds of regulations governing the forestry and wood products industries. Regulatory requirements for public participation that apply to your workplace may be in national, state, local government or industry-based voluntary or mandatory regulatory systems. For example, state legislation may require that plantation managers consult with key groups when undertaking particular work activities. Forest and plantation managers may be certified by voluntary certification schemes that specify requirements for community consultation.

Legislation, regulation and policy that may be necessary to consider include (this list may not include all relevant areas for particular workplaces but provides a guide to what regulations may apply):

- Work health and safety regulations
- Current awards and enterprise agreements
- Industrial relations
- Environmental Protection Acts and regulations
- Noise and pollution control regulations
- Transport regulations
- Industry-based Codes of Practice
- Good Neighbour Charters
- Forest certification obligations
- Organisational policies and procedural manuals, recording and reporting requirements
- Local government planning requirements.

Activity 1.1

Using the list above as a guide, research the legislation, regulation and policy requirements that might apply to planning and implementing a tree inventory undertaken by your organisation. Summarise your key findings as shown in the table below.

Legislation, regulation or policy element	Requirement
Workplace safety regulations	Undertake workplace risk assessment
Australian Forestry Standard certification	Identify opportunities for skills development
Good Neighbour Charter	Advise neighbours when using shared access tracks

IDENTIFY RESOURCE AND SITE CHARACTERISTICS

Understanding the location, boundaries, extent and complexity of the forest that is the subject of the inventory project (the 'project area') is fundamental to developing a sampling strategy and project plan.

A first step for this stage is therefore to locate information about the project area already held by the managing organisation or other parties. This information might include maps, aerial photographs and other remote sensing data and the results of previous inventory projects covering the same or similar forests or plantations.

Especially for small privately owned properties, it would be prudent to check that the mapped plantation or forest area matches property boundaries as recorded on land titles. If there is any doubt about boundaries, then land titles might need to be checked through the appropriate land titles office. Licensed surveyors might be required to sort out boundary interpretation issues on site.

A thorough ground inspection is then essential to:

- Compare the maps with actual property and forest or plantation boundary. Global positioning systems are useful for this purpose, although manual survey techniques are adequate. Aerial photographs are a valuable aid when comparing maps and actual ground features.
- Assess the location, extent and condition of access roads and tracks. These may affect the practicality of and time required for fieldwork.
- Assess access within the forest or plantation, because thick undergrowth in native forests, blackberry infestations in pine plantations, rugged and steep terrain and other encumbrances also affect the practicality of and time required for fieldwork.
- Assess forest characteristics such as species, structure, age class or classes, spatial variability to provide a basis for the stand stratification that will be undertaken in subsequent stages of plan development. Aerial photographs are invaluable when assessing these forest characteristics.

- Determine whether there are forest operations or other activities occurring in the vicinity, whether within the project area or nearby, that may present hazards. Check whether these hazards need to be assessed in accordance with risk assessment procedures, or be allowed for in project planning. Operations and activities could include road construction and maintenance, timber harvesting, regeneration and replanting work and fire protection work, including fuel reduction burning.

Activity 1.2

For your inventory project, locate and list all relevant available information about the project area. This should include maps and aerial photographs and might include previous reports on projects covering the same area and remote sensing data. Visit the site and compare that information with what you see. Write a brief report – 400 words should be enough – on the reliability of the available information and on whether the available maps match ownership records as shown on the land title.

IDENTIFY ENTERPRISE REQUIREMENTS

Tree inventory projects potentially can collect and measure data and information on a wide range of attributes. The particular attributes to be included will depend on the management organisation's particular role and objectives.

Information and data gathered by inventory projects are used by forestry and forest products organisations and businesses for a range of purposes. The inventory strategy must be selected with the particular data requirements in mind. It is therefore important at the outset to determine the organisation's specific objectives and required outcomes for each project. Examples include:

- To provide data and information about forest type, structure[1], stocking[2] and size of trees and/or other flora, species of trees and other flora, fauna, biodiversity characteristics, biomass, carbon, timber product volumes and other attributes. For timber volume inventory purposes, the plan must be clear about the categories and log grades and specifications required so that the output data enable the forest or plantation manager to meet the needs of log markets. Specifications usually include maximum and minimum length and diameter at centre or small end of logs, maximum knot size, straightness and roundness.
- For short term operational requirements, such as to set priorities required in operational plans for silvicultural work such as thinning, fertilisation, pruning, pest and weed control and for final harvesting of the timber crop.
- For medium term requirements, current tree product volumes form the basis for valuations, which are a necessary part of annual reporting for a forestry business and to assess insurance cover requirements. Valuations also provide a basis for negotiating buying or selling the business, which has become more important in the past decade or so in Australian forestry because of the increasing institutional investment in plantations.
- For longer term requirements, most importantly to determine growth rates and develop estate models to forecast potential future forest growth, wood supply and carbon sequestered.

Appropriate stakeholders, whether they are within the organisation or likely or potential external users of the results, must therefore be consulted and their support obtained for the development of the tree inventory plan and for the specific outputs required.

1 Forest structure refers to the height and density of stands of trees and components of stands, such as over-storey, under-storey and ground layers.

2 Forest stocking, also referred to as stocking rate or density, refers to the number of stems per unit area.

Activity 1.3

List some examples of objectives and anticipated outcomes that are likely to apply to an inventory your organisation initiates and explain why these are required. Summarise these using the structure in the table below or other convenient form. Some examples have been provided.

Objective/outcome required	Purpose
Estimate volume of total above-ground biomass	Sale of carbon credits
Estimate frequency of tree hollows >10 cm aperture	Assessment of habitat potential for yellow-tailed black cockatoo
Estimate category 2 sawlog yield	Response to call for tender to supply

RISK AND POTENTIAL OUTCOMES

Identifying risks and potential outcomes is a necessary first step for managing a tree inventory, as it should be for all other projects in the workplace. Risk is simply the possibility that something might go wrong. While we can never completely eliminate that possibility, the probability and consequences of identifiable risks can be minimised by identifying hazards (that is, things that present a danger or undesirable outcome), assessing each hazard according to likelihood and consequences (that is, assessing the 'risk'), and building safeguards and contingencies into the project plan.

Organisations commonly use risk management procedures based on standards developed by the International Organization for Standardization; these are referred to as ISO 31000:2009, 2009 being the year that the standards were last updated to the currently applicable version. The Australian version of these procedures are referred to as AS/NZS ISO 31000:2009. AS/NZS ISO 31010:2009 provides guidance on risk assessment techniques, that is, the overall process of identifying, analysing and evaluating risk.

These standards provide a framework that organisations can use to develop management systems for the design, implementation, maintenance and improvement of risk management processes. The aims of these processes are to increase the likelihood of achieving objectives, to identify opportunities and threats and to allocate resources to manage risk effectively.

A risk management system will require that the project manager, in conjunction with other organisational staff and project team members, work through a process including such steps as:

- Identifying workplace hazards: anything that presents a risk of something going wrong is a hazard. Safe Work Australia's *Guide to growing and managing forests* is a useful reference in identifying and assessing hazards in forest workplaces.[3] It is important to ensure that everyone involved in the inventory project understands that they are all responsible for identifying and reporting hazards.
- Assess the likelihood that the identified risk will result in an adverse outcome. Likelihood could be ranked on a scale, for example, from negligible probability through to almost certain. While this assessment is unavoidably subjective, it will help determine priorities for mitigation actions.

3 www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/growing-managing-forests

- Assess the consequences of the adverse outcome. As for assessing likelihood, consequences can be ranked on a scale, for example, from negligible impacts, minor impacts, and through to major and catastrophic impacts.
- Assess the acceptability of the consequences of risk on a scale such as: from
  - acceptable provided regular monitoring is undertaken
  - acceptable only if mitigation action is taken, to
  - unacceptable or intolerable, in which case the activity must not be undertaken.

  The risk management strategy for a low likelihood risk with negligible effects might then be to monitor but take no immediate action. At the other end of the scale, a highly likely risk with serious effects necessitates immediate mitigation action.
- Develop mitigation strategies and contingency plans to manage risks. A mitigation strategy is something that can be implemented prior to the project beginning to reduce the likelihood of a risk occurring, or to reduce the severity of the consequences if it does occur. A contingency plan is something that can be ready to be initiated when an event occurs. The aim of the strategy in each case is to reduce the risk to an acceptable level.
- Identify roles and responsibilities: all people involved in the project must understand their individual role in identifying hazards and managing risk.
- Monitor and report: the risk management plan must include a formal process for keeping records of hazards identified, risks assessed, mitigation strategies implemented and of incidents that have occurred, irrespective of whether the incidents were harmless or led to an adverse outcome. These records provide the basis for periodic review so that the effectiveness of the risk management plan can be assessed and improvements can be identified.

Some examples of likely elements of a risk management plan for a forest inventory project are shown in Table 1.

Table 1: Examples of risk management

Hazard	Potential consequences	Mitigation strategy
Project doesn't deliver required results	Project manager is sacked!	Apply the procedures described in this learning resource!
Workplace hazards in the field, *e.g.,* accidents, snake bite, bush fires or other calamities befall field team members	Injury to or death of project personnel Serious liabilities for managing organisation Serious delay in project from staff unavailability	Ensure that management plan has considered WH&S requirements Ensure necessary first aid training and accreditation for project team Provide first aid equipment and ensure that at least one member of project team has first aid training Ensure project team understands emergency response procedures
Workplace hazards getting to the field: field team members involved in vehicular accidents	Injury to or death of project personnel Serious liabilities for managing organisation Serious delay in project	Ensure all drivers are licensed and have suitable experience in the driving conditions required Ensure project team has external contact for ambulance services Assess access roads and tracks for condition and other traffic; avoid high risk access tracks
Staff leaving during project	Delays in completion Loss of knowledge that affects continuity	Locate stand-by substitute staff Ensure step-by-step documentation to facilitate hand-over to substitutes

Hazard	Potential consequences	Mitigation strategy
Project fails to deliver results on time	Results not available when required by management Costs exceed budget Further work required for acceptable results	Develop and apply management plan, including identifying stages, tasks and time lines, that considers all foreseeable relevant factors Ensure project is managed by people with required skills and experience Ensure that sampling strategy is reviewed by suitable inventory specialist Ensure data collection is in accordance with sampling strategy Monitor progress of tasks against time line and adjust plan as required
Loss of inventory data	Cost of re-collecting data Delays in completion	Provide system for data recording and protection Ensure paper records are copied at the end of each day's work Ensure appropriate back-up of computer records
Sample plot data inadequate to derive required results	Results not available when required by management Further field work required, at additional cost	Ensure sampling strategy is soundly based and independently reviewed before work begins
Other risk	Other effect(s)	Another strategy

Risk management cannot be effective unless all people who have a role in the project, directly or indirectly, are involved in the process and support the procedures specified to mitigate the identified risks. This requires communication and consultation in the risk identification and assessment stages and in the development of mitigation strategies. Effective risk management also requires periodic review to determine whether additional hazards have arisen that must be assessed.

Activity 1.4

Study your organisation's risk management procedures and risk management components of standard operating procedure/s and other relevant documents. Identify the elements of these that would apply to undertaking a tree inventory project. Examples have been provided. Your conclusions can be summarised using the structure in the table below or other convenient form.

Document	Risk management element	How this element applies to an inventory project
Company risk management plan		
Standard operating procedure for inventory projects		
Workplace safety plan		

Standard operating procedure for forest operations		
Code of Forest Practice		

Assessment 1

Locate a record of a tree inventory. Identify 5 potential but realistic risks. Develop a risk management strategy for each of these risks using the following steps, each of which is explained above:

Step 1. Identify hazards
Step 2. Assess probability of occurrence
Step 3. Consider consequences of hazard being encountered
Step 4. Summarise risk assessment
Step 5. Identify actions that can be taken to mitigate risk
Step 6. Develop contingency plans that can mitigate risk
Step 7. Identify person responsible for implementing each action and contingency plan.

Your conclusions can be summarised using the structure in Table 1 or other convenient form.

2. PREPARE FOR A TREE INVENTORY

This part of the learning resource addresses:

- researching and analysing the techniques used in forest inventory projects so that a suitable sampling strategy can be selected
- consulting appropriate stakeholders to obtain their support for the development of a tree inventory plan based on the selected sampling strategy
- obtaining management approval for the inventory management approach.

RESEARCH INVENTORY REQUIREMENTS

This section delves into the science, particularly the sampling theory and statistics, behind forest inventory. As project manager, you will need some knowledge of sampling theory and statistics to help understand the methods suitable for a particular inventory project. Sampling and statistical analysis are necessary in forest inventory because it is not practical to measure every tree in a forest, and because there are considerable differences between individual trees and across areas of forest. In statistical terms, these differences are referred to as 'variability'. Samples of the forest must therefore be selected for measurement. Furthermore, the samples must be selected in a way that avoids bias, provides a precise and accurate result, and which does that cost-effectively. These concepts are explained below.

Bias and efficiency

Selecting samples for forest inventory is aimed at:

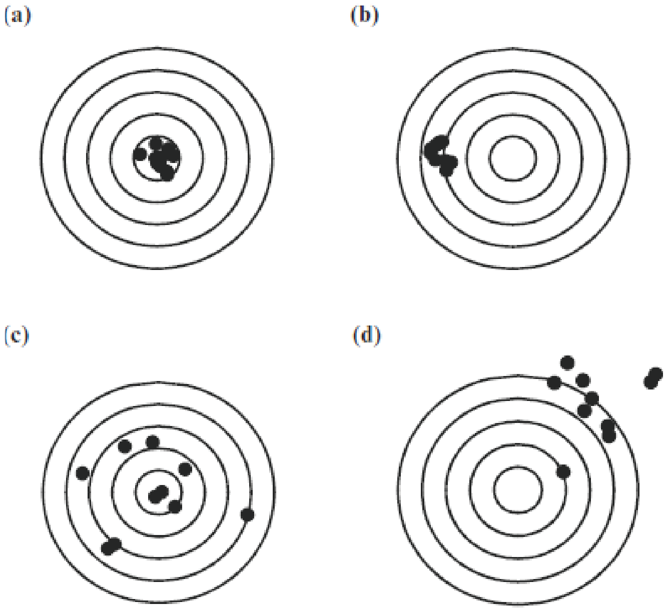
- minimising bias, that is, the systematic under- or over-representation of certain parts of the population being sampled, such as forest closest to roads or on gentler slopes or more open stands, or those with less dense blackberry vines where it is easier to walk, and
- maximising efficiency, that is, achieving the most accurate estimate for the time, effort and cost incurred, or, conversely, achieving a pre-determined minimum level of accuracy required for minimum time, effort and cost.

The concepts of bias, precision and accuracy can be explained using an analogy with bullets hitting a target, as shown in Figure 1.

In this analogy:

a) is an unbiased, precise and accurate result, which is what we are aiming to achieve
b) is a precise but biased result; in forest inventory terms, this could be the result of systematically including or excluding samples from particular parts of the forest, so that the samples measured did not truly represent the whole forest
c) is an unbiased, imprecise result, which could result from a higher than anticipated variability in the attributes being measured; conversely, this could result from not measuring enough samples
d) is a biased, imprecise result, showing a combination of these issues.

Figure 1: Bias, precision and accuracy



Source: West (2009)

Input from inventory specialists will be required at this stage to identify the strategy and techniques appropriate for the project, and within the constraints identified previously, to provide an unbiased and accurate result. Larger forest and plantation management organisations are likely to employ inventory specialists who would ordinarily be involved. Other organisations might need to engage a consultant to help with this. The Association of Consulting Foresters of Australia web site4 includes a register of members with suitable credentials and expertise.

Stratification

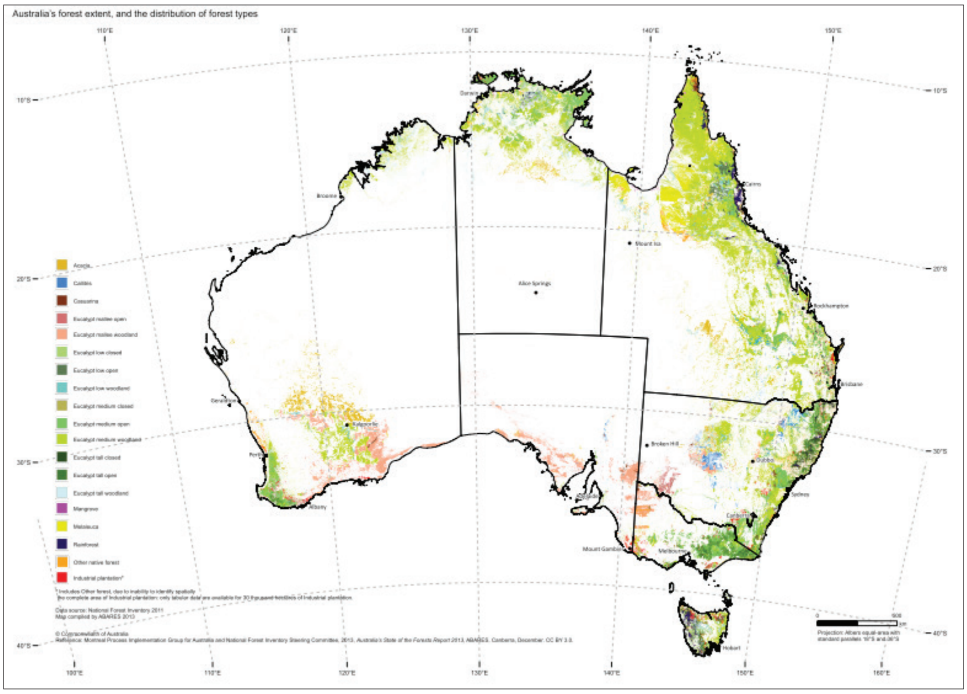
'Stratification' is a method used to improve the accuracy of the estimated stand attributes for a given level of sampling intensity. Stratification means sub-dividing the project area into identifiable strata each of which comprises stands of similar, age and structure or which generally appears to be more similar than other stands. The aim is to identify strata so that, in statistical terms, the variability within each stratum is less than the variation among the strata.

The project area could be relatively uniform and homogeneous, such as a single plantation unit in which all of the trees were planted in one year and have been managed in a similar way since planting. A 'simple random sampling' method would then be appropriate for deciding where plots should be located. 'Stratified random sampling' is appropriate where the project area varies significantly in age, species, stocking and structure. This is typically the situation in native forests and in large plantations covering many different planting years and where thinning or harvesting has affected the stocking or structure.

The forest stratification system used at a national scale for Australia's National Forest Inventory, for example, is shown in Figure 2. This stratification system is based on species and species group, combined with density and canopy height categories. Eucalypt forests are categorised into 3 height classes (low, medium and tall) combined with 3 density classes (woodland, open and closed) and a separate species grouping (mallee).

4 www.australianconsultingforesters.org

Figure 2: Forest stratification used in Australia's State of the Forests Report



Source: Montreal Process Implementation Group for Australia and National Forest Inventory Steering Committee, 2013, Australia's State of the Forests Report 2013, ABARES, Canberra, December.

Strata need not be contiguous, that is, separate forest patches that appear to be relatively similar can be included in the same stratum.

Each stratum is sampled separately when undertaking the inventory project. The results for each stratum are then combined to determine results for the whole project area.

Readily identifiable strata in a plantation forest might be:

- stands planted in a particular year
- stands with different stocking [number of trees per unit area] because of variable survival rates after planting or as a result of thinning
- stands located on particular soil types or positions in the landscape, such as swampy ground or shallow soils
- riparian reserves (sites adjoining streams and drainage lines reserved to protect water quality and other values).

Readily identifiable strata in a native forest might be:

- stands regenerated in a particular year following timber harvesting or wildfire
- stands affected relatively recently by wildfire
- stands located on particular soil types or positions in the landscape, such as riparian areas, ridges, swampy ground or shallow soils
- different species or species groups
- different growth stages, such as regeneration, advanced regrowth, mature and senescent
- areas with observably different stocking, that is, sparser and denser stands
- areas with observably different canopy height
- combinations of these attributes.

Activity 2.1

List and describe the forest strata you can identify in the photograph.

Figure 3: Forest strata

Photo: University of Tasmania

Stratum	Description
1	pine plantation, x years old
2	
3	
4	
More?	

Sample plots

As discussed above, inventory projects measure samples because it is not practical to measure every tree in a forest. Samples can be:

- selected individual trees
- measurements along strips or lines
- plots of various sizes and shapes [square, rectangular or circular] to suit the circumstances
- measurements taken at points.

Plots and point measurements are required for most forest inventory purposes. Measurements along strips can be useful if data on topography or differences in forest composition from site to site are required, as might be the case for a floristic (that is, plant species) survey in a native forest or a residual biomass survey in a harvested plantation or native forest coupe.

The size, shape and selection of plots or points are based on an assessment of the variability of the forest and the data outputs required. The sample plot must contain sufficient trees to ensure that sampling error is within acceptable limits. A range from 15 to 20 trees would generally be sufficient for a timber volume inventory. The plot size will therefore depend on the number of trees per unit area, that is, the 'stocking 'rate of the stand. Larger plots will therefore be required in sparser stands, that is, stands with lower stocking rate.

Circular plots usually work best for native forests because stocking and spacing among trees tends to be random and variable. Circular plots can also be suitable for older plantations that have been thinned substantially, so that the original planting rows no longer can be seen.

Table 2 gives a guide to convenient sizes of circular plots that should ensure there are enough trees in each sample for a range of stocking rates.

Table 2: Plot size according to stocking

Stocking rate (stems/hectare)	Plot size (hectares)	Radius of circular plot (metres)
100	0.2	25.2
200	0.1	17.8
400	0.05	12.6
500	0.04	11.3
600	0.033	10.2
800	0.025	8.9
> 1000	0.02	8.0

Source: Abed and Stephens (2003)

Rectangular plots are usually suitable for plantations where the rows that the trees were first planted in are still readily discernible. Plot sizes used in plantations are typically 0.04, 0.05 and 0.10 hectares. Dimensions can be selected depending on row spacing and, if the plantation has been thinned, allowing for the extraction row frequency. The plot width should be a multiple of the row spacing and the length adjusted to achieve the required plot area.

The commonly used point sample is an 'angle count', which is simply a count of the number of trees that exceed a specified apparent diameter when viewed from the sample point location. These measurements, which are taken using a Spiegel Relaskop or an optical wedge prism, give priority to the larger trees that provide a high proportion of the stand stem volume. This can therefore be a cost-effective method in stands with appropriate features, commonly in native forest situations with lower stocking and higher variability in tree size. While the concept of and practice of angle count sampling is fairly simple, many factors can lead to errors. A small difference in sample count can lead to a large difference in the estimate of stand volume. Field staff undertaking such sampling should therefore be trained carefully. Wood *et al.* (1999) provide good advice on this.

Sampling plots or points can either be located at random or systematically, for example, on a grid. They might be measured once or might be marked permanently so that they can be re-measured some time after. Re-measurement would be used for purposes such as to assess tree growth rates or changes in composition or structure of flora.

The number of plots required depends on the variability of the attribute being measured and the sampling error[5] considered acceptable. If there is a wide range in the value of the attribute, for example, as stocking of trees of a particular growth stage, such as regeneration, number of individuals of a particular plant species being monitored, or diameter of timber crop trees, then more samples will be required to achieve a given sampling error.

Examples of how variability and the number of plots measured affect sampling error are shown in Table 3.

Table 3: Number of sample plots in relation to variability and sampling error

<table>
<tr><th>Number of plots</th><th>Low variability</th><th>Medium variability</th><th>High variability</th></tr>
<tr><td>5</td><td colspan="3">Minimum number required for statistical comparison</td></tr>
<tr><td>6</td><td>10%</td><td rowspan="2">Estimate too poor</td><td rowspan="5">Estimate too poor</td></tr>
<tr><td>8</td><td>8%</td></tr>
<tr><td>10</td><td>7%</td><td>18%</td></tr>
<tr><td>20</td><td>5%</td><td>12%</td></tr>
<tr><td>24</td><td>4%</td><td>11%</td></tr>
<tr><td>26</td><td>4%</td><td>10%</td><td>20%</td></tr>
<tr><td>30</td><td>4%</td><td>9%</td><td>19%</td></tr>
<tr><td>40</td><td>3%</td><td>8%</td><td>16%</td></tr>
<tr><td>50</td><td>3%</td><td>7%</td><td>14%</td></tr>
</table>

Source: Abed and Stephens (2003)

In Table 3, 'Low variability' would be that found for tree size in a thinned pine plantation, where the suppressed and mal-formed trees have been removed. 'Medium variability' in tree size may be that found in fairly uniform unthinned plantations. 'High variability' should be assumed for most unthinned plantations and in native forest situations.

Sampling strategies

This section considers the various sampling strategies available. The sampling strategy used determines the way in which sample plots are located in the forest or plantation. The basic options for sampling strategies, listed in generally increasing level of complexity, are:

- simple random sampling
- systematic random sampling
- variable probability sampling
- cluster sampling
- regression sampling
- multi-stage or multi-phase sampling.

More complex sampling strategies can provide greater levels of accuracy for lower cost. However, they also require more complex calculation procedures, which entail a higher level of expertise and higher cost.

Simple random sampling

Theoretically, the most statistically appropriate sampling strategy is to allocate sample plots randomly within each stratum of the forest or plantation. Each plot location is selected entirely by chance, such as by using a random number generator to select map coordinates. The set of samples is therefore an unbiased sample. This is conceptually simple and is a commonly used strategy. However, it has drawbacks, such as the possibility that none or few plots might be located in some parts of the forest unless a larger number of plots is measured and

5 Sampling error is the percentage above or below the average value for the attribute measured from the samples where the actual value for the attribute is likely to occur. Sampling error is stated for a particular level of 'confidence', or certainty, commonly 95%.

that might not be efficient. This method is often more suitable for larger areas of native forest where there is no obvious trend or pattern in the characteristics being measured.

Systematic random sampling

Systematic random sampling uses a grid or other system to locate the plots. This ensures that all parts of the forest are covered. However, the corollary is that bias might be introduced because once the starting point is located the locations of all other sample plots are fixed in relation to the starting point. This means that, if there is some pattern inherent in the trees, the grid or pattern used could accidentally sample a disproportionate number of sites with particular characteristics. For example, using a grid to locate litter sample plots in a thinned pine plantation might place too many plots between the retained rows or in the extraction rows. However, this problem is unlikely to occur and can be avoided, for example, by ensuring that the grid interval does not match an exact multiple of the row spacing in a plantation inventory situation.

Variable probability sampling

It can be more cost-effective for inventories of timber volumes to locate a higher proportion of sample plots in strata that are likely to have greater timber volumes. Sampling these strata at greater intensity is likely to improve the overall precision of the inventory, which would be efficient statistically and would get a better result for the cost. This sampling strategy is referred to as variable probability sampling, because the probability of sampling is varied according to the likely level of timber resources in each stratum. This approach could be more suitable for an inventory of a native forest with apparently significant differences between resources in each mapped stratum.

Cluster sampling

The cluster sampling procedure is to divide the forest into sampling units, or clusters, each cluster being a small-scale representation of the entire forest. That is, the cluster should include a representative cross-section of all the various forest types, growth stages and other attributes in the forest. For this to work, the forest must be homogeneous, that is, apparently uniform. An individual cluster is then selected at random and plots selected randomly are measured. The results are taken to be representative of the entire forest. Estimates of values for the entire forest are therefore obtained from a much smaller number of samples than would be required if the entire forest was sampled and travel time is reduced because the samples are all within one part of the forest. However, sampling error is likely to be higher because it will be difficult to ensure that the cluster is truly representative of the entire forest.

Regression sampling

Regression sampling is undertaken by first measuring variables that can be more readily measured across the entire forest, that is crown cover, density and or height. These can be measured from remote sensing data, such as LiDAR[6] or other data obtained relatively easily from the aerial photographs, satellite imagery or other remote sensing. The forest is then stratified based on those measurements. Plots are measured within each stratum. A regression relationship is then developed between the remote sensing data and the plot data and the regression relationship is used to estimate volumes or values for the entire forest. Because of the inherent variability in remotely sensed data, this method is more suitable for regional assessments where an indicative resource estimate is required. It would not by itself provide data sufficiently detailed and accurate for purposes such as operational planning, valuations and growth modelling.

Multi-stage or multi-phase sampling

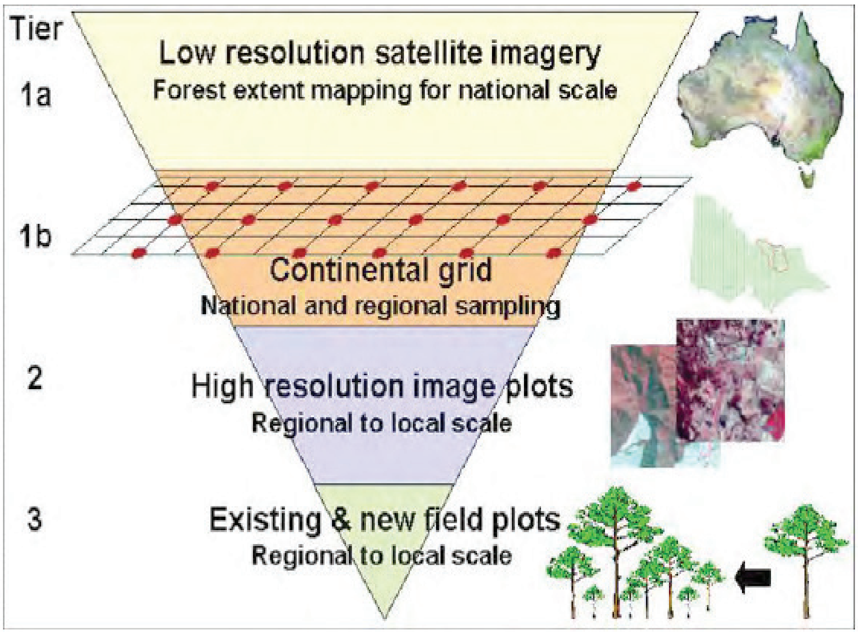
Multi-stage or multi-phase sampling procedures are only likely to be used in inventories of large areas, most likely for regional or wider area surveys of native forests. The proposed 'Continental Forest Monitoring Framework' is an example of these on a large scale. This concept combines satellite imagery to provide nationally consistent estimates of the scale of woody vegetation across all land tenures Australia wide, a grid of sampling points

6 LiDAR is a remote sensing technology that can provide high-resolution images of objects. Refer to http://www.youtube.com/watch?v=-VmAy6rxt-U for a short demonstration.

to determine where more detailed measurements would be undertaken, high resolution remote sensing data at plots to calibrate and validate the low resolution remote sensing data and finally field plots where measurements of tree and other vegetation data and environmental attributes are collected. This system is illustrated in Figure 4.

Finally, no sampling strategy for timber inventories can obtain more accurate log volumes than measurements taken from logs actually harvested. Data collected from harvest coupes within the same or similar forest or plantation types can be used to verify and adjust data from inventory projects.

Figure 4: Continental Forest Monitoring Framework



Source: Wood et al. (2006)

Case studies

This section outlines a few hypothetical subjects for inventory projects and explains some of the factors that would be considered when an inventory sampling strategy is selected. This will help to explain how the concepts outlined above can be applied when considering which sampling strategy is suitable for particular areas and types of forest.

Example 1: 10 000 hectares of mixed age native forest

Native forests are typically quite variable in tree age and density, reflecting natural variability related to site differences (for example, soils, slope and aspect) and also reflecting disturbance from fires and timber harvesting that result in patches of regeneration of various ages. Stratification will probably be essential for an inventory in this situation.

Inventory projects for native forests might require collection of data and information for a wider range of attributes – such as forest structure, species, habitat features – other than is usual for plantations, where timber resources are usually the only interest. A more complex data collection method might therefore be required for native forest inventories. Simple random sampling is likely to be suitable approach for basic timber inventory data. That could be combined with simultaneously measuring other attributes on a sub-sample of plots if additional information is required. More complex strategies that require remote-sensing data, such as regression sampling or multi-phase sampling, would probably not be warranted for a 10 000 hectare area or less of native forest.

Example 2: 10 000 hectares of radiata pine plantation

Radiata pine plantations are established in units or compartments of one planting year. Each compartment might be a few 10s to a few hundred hectares. Each unit is managed in a similar way throughout the production period, or rotation.

A 10 000 hectare plantation would probably comprise a range of planting years, treatments, harvesting histories and site productivity. A stratified random sampling method where each planting year and each unit with a different harvesting history is considered a separate stratum would therefore be appropriate.

It would also be prudent to consider whether inherent site productivity differs significantly across the 10 000 hectares. Further sub-division of strata might then help get a more accurate result.

Example 3: 500 hectares of 6-year-old blue gum plantation

A 500 hectares plantation that was all planted in the same year, has all had a similar history of fertilising, etc., and has no apparent significant variability in growth across the 500 hectares could be considered one stratum. Locating sample plots on a grid would then be appropriate. Separate strata should be identified if stocking or growth appear to differ significantly across the plantation, such as often happens, for example, where there are patches of less fertile, more fertile, shallow or intermittently water-logged soil.

Activity 2.2

Assess three available reports on forest and or plantation inventory projects to identify the sampling strategy that was applied, and compare the key factors that were considered when that strategy was selected. Explain why the strategy used was [or was not] appropriate for the particular project. Summarise your findings using the structure in the table below or other convenient form.

Forest inventory project	Sampling strategy used	Why was that sampling strategy used?	Was that approach appropriate?
1			
2			
3			

References:

Fenner School, Australian National University, 1998, Eden compartment case study: http://fennerschool-associated.anu.edu.au/mensuration/BrackandWood1998/EDROMSMP.HTM

Queensland CRA/RFA Steering Committee An inventory of private native forests of south east Queensland, http://www.daff.gov.au/__data/assets/pdf_file/0005/49028/qld_se_raa_se1.4.pdf

Activity 2.3

Describe the key features of the forest you have selected as the subject for development of a tree inventory in terms of the features (size, type, ages, strata, apparent productivity differences, variability, etc.) considered in the explanation of sampling strategies and the case studies described above. Select a sampling strategy appropriate for the forest. Use the case studies as a model for how to do this.

CONSULT WITH STAKEHOLDERS

Depending on the type of forest or plantation organisation, stakeholders, or people with an interest in the inventory plan, could include:

- managers of a native forest or plantation estate
- shareholders or investors in a plantation business
- customers, contractors and operational staff
- professional, technical or administrative staff
- governments and the general community.

Having selected a sampling strategy appropriate for the forest, it is necessary to ensure that each relevant stakeholder is confident that that strategy can provide the data and information needed. A suitable procedure to do that could be:

- Prepare a draft statement of objectives and strategy outlining your understanding of the objectives and anticipated outcomes required and the sampling strategy you consider appropriate.
- Distribute the draft statement of objectives and strategy to all relevant stakeholders and invite written comments.
- Conduct one-to-one meetings, group meetings or workshops, as suits the circumstances, with all relevant stakeholders to assess their satisfaction with the recommended objectives and strategy
- Revise the draft statement in accordance with responses.

APPROVALS

Management approval is necessary to proceed to detailed planning. Prepare a briefing paper requesting approval to proceed. The briefing paper should summarise:

- the process used to develop the draft statement of objectives and strategy
- the process used to consult with stakeholders.
- responses from stakeholders and how these were addressed
- the recommended final objectives and strategy.

3. PREPARE TREE INVENTORY PLAN

This section describes the administrative tools, physical resources and recording methods typically used in forest inventory. These include the technologies available for mapping the forest, the extent and characteristics of which were identified in Section 6.3. We must also consider the human resources required, and the skills typically included in a forest inventory team. The costs of implementing the plan must be estimated and quality assurance systems established. This information can be brought together into a plan that enables communication with stakeholders and the project team.

IDENTIFY TOOLS AND EQUIPMENT

This section outlines the types of administrative tools, computer-based systems, other technology and physical resources and recording methods typically used in forest inventory.

Tools, systems and technology

Remote sensing

Remote sensing in forest inventory refers to collecting data other than by direct contact with the trees on the ground. By far the oldest form of remote sensing is aerial photography, which has been available for forest mapping and inventory uses for at least half a century. Despite the huge technological developments in that time, photographs taken from aircraft are still probably the single most widely used and practically useful method of remote sensing used in forest and plantation mapping and to plan inventory projects. Images taken from satellites Sources of aerial photographs, as well as maps and other remote sensing imagery, are listed in *References, sources and further reading.*

Geographic information systems

Geographic information systems (GIS) are computer-based systems that receive, store, manipulate, analyse and present geographical data. GIS use digital information from maps, photographs or imagery in layers (such as topography, stream systems, roads and vegetation cover) that can be over-lain in whatever combination is needed for specific tasks far more efficiently than is possible with traditional paper maps. GIS software is readily available for forestry uses. Esri Australia[7] is a major supplier of such software.

Proprietary software – inventory tools

While many forest and plantation management organisations have developed their own software tools and systems for their inventory requirements, software developed for sale by service providers is also available. One of the main providers is Atlas Technology[8], which is a business owned by the forestry research organisation Scion New Zealand.

The software available and their function includes:

- 'Assessment Planner': a program installed in a geographic information system to create plot layouts and generate plot location maps for inventory projects
- 'FieldMan': for entering field inventory and other data
- 'Cruiser'[9]: for generating log volume data by product based on the data collected from plots

7 https://esriaustralia.com.au

8 http://www.atlastech.co.nz

9 Atlas Cruiser replaced a program referred to as MARVL (method of assessment of recoverable volume by log type). Some people working in forest inventory might still use the former name.

- 'Geomaster': for managing stand records and provide links to a geographic information system
- 'Forecaster': to prepare yield tables for forest management planning.

Publically available software – inventory tools

Private Forests Tasmania's 'Farm Forestry Toolbox'10 contains about 20 useful forestry-related programs including for basic surveying and mapping, inventory for timber and carbon and forest growth projections.

Proprietary software – estate models

Estate models are computer-based systems that combine all of the inventory data, usually combined with mapped data in a geographic information system, and that use those data to develop information and projections for the entire forest or plantation estate managed by an organisation. These systems can be used, for example, to develop operational plans, to determine optimum thinning and final harvesting regimes, to forecast growth and timber product yield and to undertake valuations. Many forest and plantation management organisations have developed their own estate modelling systems, either individually or in partnership with other organisations that manage similar resources.

Available proprietary software estate models include 'Woodstock'[11] and 'Harvest Manager'.[12]

Biometric models

Biometric models are mathematically based relationships among basic measureable data, such as tree height, diameter and shape, and output data, commonly stem or log product volumes for individual trees or for areas of trees. When combined with growth rate information, biometric models are used to extrapolate from tree inventory data measured at one particular time to forecast future outputs. Biometric models are developed using data measured from sample plots, permanent sample plots and or research trials.

Key precautions to take when relying on biometric models in a tree inventory project are to ensure that the models used are developed and calibrated for forest or plantation with similar characteristics to those of the trees being inventoried. A simple example is a model that calculates stem volume from tree height and diameter at breast height.[13] This type of model requires data on tree taper, that is, change of diameter with height. Tree stem taper varies among tree species, even among the same species growing in different regions, so that the model must be based on species and regionally appropriate data.

Physical resources

The following list gives an idea of the basic tools, equipment and other physical resources that are typically required for measurement, recording and other purposes by forest inventory field crews:

- GPS (global positioning system) device, hand-held, for navigation to plot locations (a GPS is optional – measuring along a compass bearing from a known mapped location would usually be sufficiently accurate; however, a GPS would probably make it easier if a previously measured plot must be re-located exactly for re-measurement)
- linear measuring tape (typically 30 or 50 metres length) for locating and laying out plots; the procedure for setting out a plot is demonstrated at: http://www.youtube.com/watch?v=lfU5BIbln9Y
- hip chain distance measurer, for measuring distances travelled on foot through the forest
- diameter tape (i.e., a girth measuring tape calibrated by a factor of 'π', so that the tree diameter is measured directly by wrapping the tape around the tree at 'breast height', that is, 1.3 metres from the ground on the uphill side of the tree); the procedure for measuring tree diameter and determining basal area is demonstrated at: http://www.youtube.com/watch?v=QWuJoLqrRac
- laser rangefinder distance measuring device, such as 'Vertex hypsometer', for measuring distances and tree heights (height can also be measured using a clinometer, linear measuring tape and trigonometry)

10 http://www.pft.tas.gov.au/index.php/farm-forestry-toolbox-registration

11 www.remsoft.com/forestry

12 http://www.atlastech.co.nz

13 Breast height, that is, 1.3 metres above the ground on the up-hill side of the tree, is the standard place to measure stem diameter in Australian forestry. In New Zealand the standard height is 1.4 metres because New Zealanders are, on average, taller than Australians.

- Abney level or clinometer, for measuring slopes so that ground distance measurements can be corrected from slope to horizontal distance and for measuring angles from which to calculate heights; the procedure for measuring tree height using a clinometer is demonstrated at http://www.youtube.com/watch?v=q4LhwniXAJI
- wedge prisms of various factor for basal area measurements
- compass, for locating plots and finding the way back to the vehicle when the GPS batteries run flat
- spare batteries for electronic devices
- corner posts or stakes for marking plot centres or perimeter
- satellite phone, two way radio or mobile phone (if there is reception)
- data recording device (i.e. waterproof paper-based sheets, or electronic data logger), clipboards, pens and pencils, calculator
- flagging tape and or paint for marking routes, plot centres and trees
- maps and/or aerial photographs to which has been added project area boundaries, plot locations and any other features that will help the field workers do the job
- camera to take a visual record, which could be useful if attributes such as stand structure and understorey density are to be assessed
- water bottles, because it is usually dry in the forest
- safety equipment such as a first aid kit, hard hat, sun protection, high visibility vest.[14]

Other specialised equipment will be required if attributes such as leaf litter or soil carbon are included in the inventory. Suppliers of inventory equipment are listed under **Technology, equipment and data** in the ***References, sources and further reading*** section of this learning resource.

Activity 3.1

List the inventory equipment available at your workplace. Is any essential equipment not available? Where could that equipment be obtained?

HUMAN RESOURCES

Undertaking an inventory will typically a team comprised of people with the following responsibilities:

- Statistician or forest sampling specialist – responsible for designing the sampling program, processing and analysing the data when they come in from the field, performing statistical calculations to determine if target precision has been met. This is a specialised skill, maybe one that smaller forest or plantation managers do not employ. Consultants or other external advisers would then be required. This option is considered in more detail below and in Section 2.2 of this learning resource.
- Geographic information system or mapping specialist – responsible for developing the forest stratification system, mapping of plot locations, and for producing maps.
- Logistics officer – responsible for procurement of field equipment, arranging travel plans, organising training if applicable, obtaining required permissions and approvals, and ensuring compliance with work health and safety procedures, including ensuring staff have appropriate first aid training.
- Field team leader – responsible for ensuring a safe working environment is established and monitored throughout the sampling activities, overseeing implementation of field measurements in accordance with the standard operating procedures, planning daily activities, reporting planned activities and progress to the project manager and supervising the data collection procedures.

14 Additional information about first aid requirements is provided in the Code of Practice for First Aid in the Workplace: http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/693/First%20aid%20in%20the%20workplace.pdf

- Field measurement crew – responsible for taking field measurements in accordance with the standard operating procedures and under the instruction of the field team leader, entering data onto the standardised templates, and sending data to the statistician or sampling specialist.

One person may perform more than one of the above functions.

Employees of the managing organisation or contracted staff or service providers could undertake the inventory project. Some plantation management organisations have sufficient scale to warrant developing and maintaining their own inventory skills in-house. Smaller organisations might find it more cost-effective to engage consultants or contractors. Which method is most practical and cost-effective will depend on factors including:

- the type and scale of the project
- technology and technical abilities required and whether these are available 'in house'
- the time and budget available.

INDUCTION AND TRAINING

Organisational induction and training will be required if the organisation recruits people for the inventory team as employees. This will cover work place health and safety, emergency response procedures, protective clothing and equipment, environmental management and other requirements. While consultants or contractors are responsible for ensuring training for their own team, as project manager for the contracting organisation, it would be prudent for you to obtain verification of the consultant's or contractor's employees skills and accreditation.

Training on specific inventory plan requirements will cover:

- project objectives, strategies and methods,
- reporting mechanisms for monitoring time and resources used,
- inventory techniques, including use and maintenance of tools and equipment,
- recording inventory results.

Basic training in tree measurement methods and equipment may be assisted by publications such as the *Tree measurement manual for farm foresters*[15] and the Master Tree Growers publication *Tree and forest measurement.*[16] Private Forestry Tasmania's 'Farm Forestry Toolbox' contains 20 useful inventory programs.[17]

Details and links to these are also listed in References, sources and further reading, together with other publications and sources of information on inventory methods.

15 http://data.daff.gov.au/mapserv/plant/report_list.phtml

16 http://www.agroforestry.net.au/edit/pdfs/5%20Tree%20and%20forest%20measurement.pdf

17 http://www.pft.tas.gov.au/index.php/farm-forestry-toolbox-registration

Activity 3.2

Research the professional staff and employees' skills available in your organisation for undertaking an inventory. Summarise your findings using the structure in the table below or other convenient form.

Position	Skills

Assessment 2

Outline the advantages and disadvantages of using employees, rather than consultants or contractors to undertake various types of inventory project needed by your organisation.

ESTABLISH A QUALITY ASSURANCE SYSTEM

It is good practice for an inventory project to include a quality assurance system in the project plan. A quality assurance system specifies procedures for checks, audits, and corrective actions to ensure that sampling is conducted to a satisfactory standard and that errors are avoided. A quality assurance system should include a feedback mechanism to ensure continuous improvement over time, and to ensure that the sampling program is meeting the requirements of the organisation. Quality assurance procedures should cover mapping, field measurements, data entry and analysis, data filing and storage.

The **mapping specialist** must be formally trained in geospatial analysis. Mapping methods must be undertaken in accordance with standard operating procedures covering processing of imagery, spatial projections, obtaining and processing data, data completeness and consistency and a procedure for recording and tracking of errors.

The **field measurement crew** must be well trained in all aspects of the field inventory, and must conduct field measurements (including required calibration) in accordance with standard operating procedures. The field team leader must supervise the field crew at all times to ensure correct implementation of standard operating procedures. To minimise field transcription errors, it is good practice for the person recording the measurement to verbally repeat the measurement back to the measurer. It is good practice to establish an internal audit program for field measurements, whereby a proportion of field plots (5 – 10% would be adequate) are re-measured by an independent field crew.

It is good practice to prepare **standard operating procedures for data entry processes**. Where field sheets are used, ideally the person responsible for transcription of field data into spreadsheet format should be the same as the person who undertook the measurements. This way errors related to interpretation of handwriting can be minimised. An independent person should be assigned to check a sub-sample (approximately 10%) of spreadsheet data against the original field sheets. The spreadsheets should include automated data entry checks, for example by activating an alert or preventing data entry outside the expected range (for example, by not allowing entry of tree height values in excess of the tallest tree in the stand).

It is good practice to prepare **standard operating procedures for naming of data files**, including information about version numbering and procedures for review of documents and files. Version control can be maintained by having document control sheets on the cover page of all documents, stating the current version number and date modified, as well as the person responsible for maintaining the 'master' version of the document. Original copies of all field measurement datasheets and laboratory data should be filed in the head office in a secure location, and soft copies of all datasheets should be stored in multiple locations. Professional data managers can be engaged for specific advice on data storage procedures.

COMMUNICATION PLAN

To communicate the inventory project to stakeholders we need a plan that summarises the project objective, methods, physical and human resources and financial requirements required to undertake the project and that explains step by step how the project will be undertaken. Components of the plan would therefore typically include:

- project objective
- inventory method
- number and type of sample plots
- attributes to be measured at plots
- measurement and recording methods
- quality assurance requirements
- skills required
- team numbers
- team recruitment or contractor selection process
- equipment required and where it can be obtained
- vehicles required and where they can be obtained
- work health and safety requirements, as required by the risk assessment
- emergency response procedures, as required by the risk assessment
- a budget developed by itemising costs of all inputs and expenditure required
- time required for each project stage
- overall timeline and budget
- drafting project report
- communicating preliminary results to internal and, if appropriate, external stakeholders
- the process required for finalising the report and disseminating findings.

The above list, adapted as appropriate for your circumstances, could form the basis for the structure of the inventory plan.

When developing the plan it will be necessary to estimate the time, people, equipment and technology required and to develop a budget using that information and cost estimates. Consultation will then be required with the organisation to determine whether this suits the resources available or whether the plan must be reconsidered.

Typical key tasks for a forest or plantation inventory project are set out by stages below.

Table 4: Key stages, tasks, deliverables and dates

Stage	Task	Key deliverable for each task	Due date
1	1.1	Project objectives and preliminary risk assessment	Week
	1.2	Selection of sampling strategy and identification of plot locations	Week
	1.3	Selection of contractor or in-house project team and specialist advisers	Week
	1.4	Training of project team	Week
	1.5	Acquisition of equipment and vehicles required	Week
	1.6	Review risk assessment	Week
2	2.1	Commence field data collection	Week
	2.2	Complete X number of sample plots	Week
	2.3	Complete Y number of sample plots	Week
	2.4	Complete balance of sample plots	Week
3	3.1	Commence data entry and analysis [may overlap with 2.3]	Week
	3.2	Complete data entry	Week
	3.3	Check data for errors and inconsistencies	Week
	3.4	Analyse data and generate results	Week
4	4.1	Commence report writing	Week
	4.2	Brief managers and other stakeholders on preliminary results and concerns	Week
	4.3	Finalise data analysis and draft report	Week
5	5.1	Circulate draft report to stakeholders	Week
	5.2	Assess feed-back and finalise report	Week
6	6.1	Project review	Week

Assessment 3

Prepare an outline 'table of contents' for a work plan for a tree inventory relevant to your organisation's business. You may use the heading on the page prior to help.

4. MANAGE THE IMPLEMENTATION OF TREE INVENTORY PLAN

To manage implementation of an inventory plan successfully, a system is required that ensures that participating stakeholders understand their responsibilities and plan requirements to ensure that objectives are met and outcomes are of expected quality. Risk management should be reviewed periodically. The system must also enable monitoring of progress and record keeping to monitor finances and resources so that a review of plan outcomes and objectives can be undertaken in the final stage. A variety of computer-based project planning tools, such as Microsoft Project, that facilitate documentation of project stages, tasks and time lines is available to help with these functions.

Microsoft Project is a project management software program, developed and sold by Microsoft, which is designed to help a project manager develop a plan, assign resources to tasks, track progress, manage the budget and analyse workloads. While part of the Microsoft Office group of software packages, it has never been included in any of the Office suites. It is available currently in 'Standard' and 'Professional' editions. While Microsoft Project is arguably the dominant personal computer-based project management software, others are available, including:[18]

- ProjectLibre
- Gantt Project[19]
- Open Workbench
- 2-plan Project Management Software
- ToDoList.

As well as the above personal computer-based software systems, there are on-line systems such as Wrike.[20]

Whatever system is used, the basic steps involved in setting up a project using project management software will typically include:[21]

- setting the project initiation date and identifying the dates and time available
- defining individual tasks and how long each will take to complete
- defining whether scheduling of each task is to be pre-determined or determined by dependence on other tasks or constraints
- defining relationships between individual tasks, that is, are they dependent or independent on other tasks or constraints and are they sequential or concurrent?
- defining the resources available, that is, the project team, other people within or contracted to the organisation, vehicles and equipment, technology services
- assigning resources to each task and the quantity or work hours each resource is assigned to each task
- defining the duration of allocation of each resource to each task.

A commonly used way to portray these details is in a 'Gantt' chart[22], a simple example of which is shown in Figure 4. A Gantt chart is one of the most popular and useful ways of showing the temporal relationship among project tasks, that is, how each task's start date, finish date and duration compares with those of each other task.

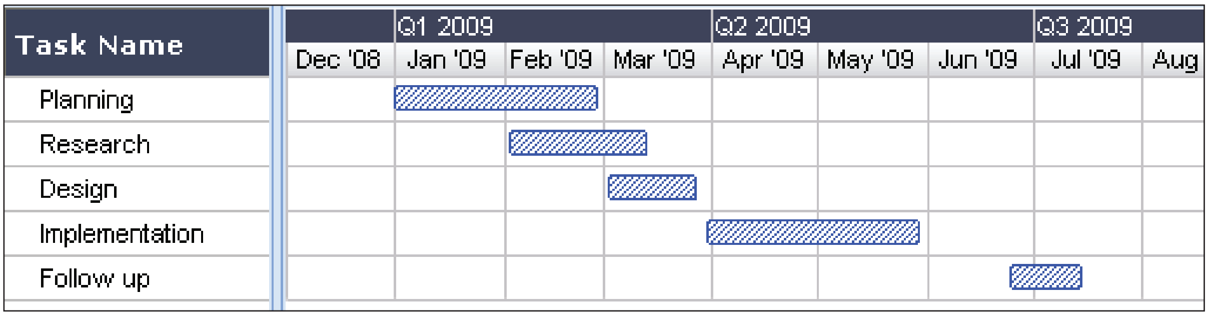
18 http://www.techrepublic.com/blog/five-apps/five-free-microsoft-project-alternatives/
19 Gantt Project can be down-loaded free of charge from http://www.ganttproject.biz
20 www.wrike.com
21 Refer, for example, to the Microsoft Project 2010 Project Management Quick Reference Guide for a detailed explanation, http://office2010.microsoft.com/en-us/templates/project-2010-quick-reference-guide-TC101731504.aspx.
22 Gantt charts are named after Henry Gantt, an American engineer who developed the idea based on a concept first devised by a Polish engineer named Karol Adamiecki (source: www.gantt.com)

Each task is listed down the left hand side of the chart and dates are shown across the top at a suitable time scale. A separate bar across the chart represents each activity. This allows you to see at a glance:

- what the various activities are
- when each activity begins and ends
- how long each activity is scheduled to last
- where activities overlap with other activities, and by how much
- the start and end date of the whole project.

One advantage of showing a project in this way is that it highlights activities that are interdependent. Critical limiting factors, where one activity must be completed before another can be started, are therefore identified. The project manager should then consider including these in the risk management plan.

Figure 4: Simple example of a Gantt chart



Source: www.gantt.com

Activity 4.1

Develop a Gantt chart using an example of the forest or plantation inventory project typically required for your organisation.

Assessment 4

Provide a communications report on the conduct of a tree inventory, what types of communications were needed to ensure the inventory was conducted effectively, efficiently and safely?

5. REVIEW INVENTORY PLAN

By this stage in the tree inventory project, the plan has been implemented, data have been collected and analysed, and the project report has been written and circulated to stakeholders. The final stage is to review what happened.

Tree inventory projects are a fundamental and recurring requirement for forest and plantation managers. It can be expected that further needs for data and information will be identified, and that further tree inventory projects will be required sooner or later. Review the completed plan can identify what went right, what went wrong, what variations were introduced during project implementation, what could have been done better, and what lessons have been learned to help guide development of subsequent plans. Reviewing each completed plan in this way can be referred to as a cycle aimed at continuous learning and improvement.

Specific questions to be asked at this stage could include whether:

- the project objectives were achieved; this will require consulting with appropriate stakeholders about their desired and actual outcomes, as discussed below
- the project was completed on time and within budget, and, if not, why not?
- variations from the plan were identified and investigated
- the inventory strategy selected proved to be the most appropriate for the circumstances, or whether refinements can be identified for future projects
- further inventory work required to complete management objectives for the project area
- issues that arose during the project still need to be resolved
- further training and development desirable for project staff
- any other actions are required and areas for improvement were identified.

These and other questions can be used to develop 'performance indicators' that provide a specific and measurable mechanism to review the plan. As well as being used to review the inventory plan, performance indicators can be incorporated into:

- staff employment contracts and agreements
- organisational business plans
- contracts for engagement of consultants and other service providers, such as inventory teams.

Stakeholders within the management organisation and external users of the results of the inventory project should be consulted when selecting performance indicators for the project so that the indicators selected reflect the range of desired and actual outcomes.

Activity 5.1

Develop a list of performance indicators that would be suitable for reviewing an inventory plan implemented by your forest or plantation organisation. Consider indicators of interest to various stakeholders. The framework below can be used to present your list.

Indicator	Stakeholder	Rationale
Lost time accidents during project implementation	Company WH&S manager; corporate management team	Identify high risk activities for further attention in risk management plan
Total project cost compared with budget	Company finance manager; corporate management team	Finance manager must reconcile company accounts Revised cost estimate required to develop budget for next inventory project
Reliable estimate of frequency of tree hollows >10 cm aperture	Friends of the yellow-tailed black cockatoo community group	Forest manager must provide advice about conservation status of yellow-tailed black cockatoo
Reliable estimate of category 2 sawlog yield	Agency commercial manager and management team	Data required for sales contract

6. BRINGING IT ALL TOGETHER

When you feel that you are ready for assessment you should meet with your assessor to agree on:

1. the most appropriate method(s) of assessment to be used to determine competence against the Unit of Competency
2. the timing of the assessment task(s).

At AQF Level 5 it is expected that you can collect and compile a range of data types and interpret, communicate and use this data. For this reason it is strongly recommended that a holistic approach be taken to assessment.

To demonstrate competence it is recommended you develop a plan to undertake a tree inventory within a sustainability framework, and where possible have a third-party conduct the inventory. You can then objectively assess the effectiveness of the plan and make recommendations for improvements in future.

If you do not have access to a workplace where you can be involved in a tree inventory it is recommended that you develop an exemplar plan and implement it on a forest in your locality.

Site assessment

Before drafting a sustainable tree inventory plan there is a substantial amount of site information that needs to be collected and assessed. Your site assessment should at least cover the following:

- Site characteristics ie size, access, slope and resource characteristics ie species, condition
- Resource use ie timber, amenity and related management objectives
- Relevant legislation and regulation, particularly related to tenure
- Neighbourhood issues
- Hazards to be considered in risk assessment

Basis of inventory

A tree inventory can be conducted for many purposes; your assessment is to be conducted within a framework of sustainable management. You will need to collect information about the following:

- Enterprise/owners policies on sustainable management
- Required outcomes of the inventory and likely use of the findings
- Who needs to be consulted so as to support the findings
- Approvals required.

Prepare tree inventory plan

A tree inventory can be a resource intensive exercise. What resources will be required to implement yours? The plan should details requirements for the following:

- People, money, time and equipment
- Systems needed to bring these all together
- Selecting an appropriate sampling strategy
- How the plan is to be communicated
- How you will ensure a quality outcome
- Documentation needed and how you will collect it
- How you will identify and manage risks

Manage implementation of the plan

It is recommended that if possible you have a third-party implement the inventory and collect the information while you oversee the process from the plan. Record the process noting:

- Were requirements clear and well communicated?
- Was the right data collected?
- Did the inventory go to budget and on time?
- Has the inventory been efficient and effective?

Review tree inventory plan

Analyse the results against the outcomes and evaluate the effectiveness of the activity. Establish what worked well and what could be improved. Make recommendations for changes to the plan based on this information.

SOURCES AND FURTHER READING

FOREST MENSURATION THEORY AND PRACTICE

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INVENTORY CASE STUDIES

Biggs, PH, and Spencer, RD, (1990). New approaches to extensive forest inventory in Western Australia using large-scale aerial photography, *Australian Forestry*, 53(3):182–193.

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Hamilton, F, Penny, R, Black, P, Cumming, F, Irvine, M, (1999). Victoria's Statewide Forest Resource Inventory—an outline of methods, *Australian Forestry*, 62 (4):353–359.

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Queensland CRA/RFA Steering Committee An inventory of private native forests of south east Queensland, http://www.daff.gov.au/__data/assets/pdf_file/0005/49028/qld_se_raa_se1.4.pdf

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WORK HEALTH AND SAFETY

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Safe Work Australia, *Guide to growing and managing forests*, http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/growing-managing-forests

PROJECT MANAGEMENT

Microsoft Project, (2010). Project Management Quick Reference Guide, http://office2010.microsoft.com/en-us/templates/project-2010-quick-reference-guide-TC101731504.aspx

REGULATORY AND RISK MANAGEMENT REQUIREMENTS

AS/NZS ISO 31000:2009: Australian/New Zealand risk management standard—principles and guidelines, Standards Australia.

AS/NZS ISO 31010:2009: Australian/New Zealand risk management standard—risk assessment techniques, Standards Australia.

Australian Standard for Valuing Commercial Forests, Version 2, Institute of Foresters of Australia Limited, Association of Consulting Foresters of Australia Division, www.forestry.org.au.

ISO 31000 – Risk management – principles and guidelines, International Organization for Standardization, http://www.iso.org/iso/home/standards/iso31000.htm

TECHNOLOGY, EQUIPMENT AND DATA

AAM Group, http://www.aamgroup.com/industries/forestry-and-environment (geospatial services – aerial survey and LiDAR)

Atlas Technologies, Scion New Zealand, http://atlastech.integral.co.nz (inventory software)

Department of Environment, Water and Natural Resources South Australia, http://www.environment.sa.gov.au/Science/mapland (maps, aerial photography, spatial and GIS data)

Forestry Tools, http://www.forestrytools.com.au (survey and inventory equipment)

Google Earth, http://earth.google.com (satellite images)

Landgate, Western Australia https://www.landgate.wa.gov.au/corporate.nsf (titles, records, maps, aerial photography, imagery)

Land and property information, New South Wales http://www.lpi.nsw.gov.au (titles, records, maps, aerial photography, imagery)

Primary Industries, Parks, Water and Environment, Tasmania, https://www.tasmap.tas.gov.au (maps, aerial photography)

Private Forests Tasmania, Farm Forestry Toolbox, http://www.pft.tas.gov.au/index.php/farm-forestry-toolbox-registration (surveying, mapping and inventory software)

Prospectors, http://www.prospectors.com.au (survey and inventory equipment)

Remsoft, www.remsoft.com/forestry (inventory software)

SELF ASSESSMENT

Before commencing on your summative assessment take a few minutes to review this workbook and ensure you feel that you are confident about your skill levels related to this topic.

Use the table below to help you check your skills which have been taken from the *Required knowledge and Skills* section of the relevant Unit of Competency. Before commencing your final assessments it is important to review any sections in which you feel unsure. Please always ask your assessor/lecturer questions about areas you are unsure about.

In the table below, read the list of skills and knowledge you should have after completing this workbook.

1. Put a tick in the "confident" column if you can do this now and a brief comment re why you believe you have this skill.
2. Put a tick in the next column if you feel you need more practice and must review the work before completing final assessments also a brief comment as to why.
3. If you require further training, complete the third column listing what training is needed. Show this list to your supervisor or assessor and ask for more time or training before completing the summative assessments.

Skills/knowledge you should have	Confident	Need Practice	What additional training do I need
REQUIRED SKILLS			
Research, technical, planning and organisational skills to manage a sustainable tree inventory			
Technical skills to undertake surveys and map information; and interpret data generated from manual and electronic surveying and mensuration			
Management skills to manage databases, prepare a tree inventory plan, undertake appropriate consultation, and undertake risk assessment			
Communication skills to use appropriate communication and interpersonal techniques with stakeholders			
Literacy skills to record and report workplace information, maintain documentation, and collect data			
Numeracy analytical skills to analyse relevant workplace information and collected data			
Problem-solving skills to identify problems and appropriate response procedures			
REQUIRED KNOWLEDGE			
Applicable commonwealth, state or territory legislation, regulations, standards, codes of practice and established safe practices relevant to the full range of processes for managing a sustainable tree inventory			

Skills/knowledge you should have	Confident	Need Practice	What additional training do I need
Environmental protection requirements, including the safe disposal of waste material and minimising environmental impact			
Organisational and site standards, requirements, policies and procedures for managing a sustainable tree inventory			
Environmental risks and hazards associated with managing a sustainable tree inventory			
Role of wood or waste products in generating renewable energy through biomass			
Using energy effectively and efficiently			
Using materials effectively and efficiently			
WHS/OHS in relation to operations			
Database management and document control systems			
Relevant species behavioural characteristics			
Silvicultural practices associated with management objectives			
Key sustainability indicators			
Mensuration theory			
Inventory tools and their application			
Trigonometry associated with surveying and tree measuring			
Established communication channels and protocols, including notification of authorities			
Problem identification and resolution strategies			
Types of tools and equipment, and procedures for their safe use and maintenance			
Procedures for recording and reporting workplace information			

FEEDBACK

This learning resource has been developed to guide you through available topical information and to set activities for you to do that help you gain knowledge and skills appropriate to your work place or situation. Your competency will be assessed through your successful completion of the activities to a satisfactory standard and submitting these for review. Please complete the following table to notify us of any errors and suggest any improvements.

Learning Resource	***Manage Sustainable Tree Inventory***

Page	Description of error	Suggested improvement
	E.g., web site link doesn't work	E.g., update link
	E.g., reference obsolete or unavailable	E.g., provide currently relevant or accessible reference, such as ...
	The activity is unrealistic and unhelpful	E.g., change it to ...

Additional comments

Click here to email your feedback form to ForestWorks

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Preparation of this training resource has been a collaborative effort between ForestWorks and the Institute of Foresters of Australia. It is one of a set of seven as follows:

1. Manage sustainability in the workplace (assessment framework only)
2. Implement sustainable forestry practice
3. Manage tree harvesting to minimise environmental impact
4. Undertake carbon stock sampling of forests and plantations
5. Manage sustainable tree inventory
6. Promote plantations as a sustainable form of landuse
7. Build and maintain community relationships.

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The project drew on the depth and breadth of technical knowledge and subject matter expertise of IFA staff, members and other experts.

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Steering committee

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