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

Learning Resource for UNDERTAKE CARBON STOCK SAMPLING OF FORESTS AND PLANTATIONS








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 ***FPIFGM5219 Undertake carbon stock sampling of forests and plantations***.

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

Sometimes you may click on a web link and the site will say it is not available. Please revisit the site when you are next working on your resource materials as web sites are sometimes "off line" for maintenance reasons. If the link is "not found" then track back to the home page in the link address and try and search from there.

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 ARE THESE LEARNING MATERIALS ABOUT?

This workbook applies to any person working in a forestry enterprise who is required to assess forests and plantations for current and future carbon stocks in a variety of work settings, including:

- Native forests
- Hardwood or softwood plantations
- Agroforestry and farm forestry plantings.

This workbook is designed to be policy-neutral. The carbon sampling program it describes is considered 'best practice', and it should be applicable regardless of Australia's broader climate change mitigation policies.

The scope of the workbook includes the following activities:

- Planning for carbon stock sampling activities
- Preparing for carbon stock sampling activities
- Conduct of carbon stock sampling
- Data analysis and interpretation
- Use of growth models to predict biomass and carbon stocks.

It should be noted that the focus of this workbook is on carbon sampling techniques. Detailed instructions on forest measurement techniques are covered in the workbook *FPIFGM6203 – Manage sustainable tree inventory.*

Learners can also access the resources listed at the end of this workbook for more information of this kind.

EMPLOYABILITY SKILLS

This workbook provides an opportunity to develop and apply to your job employability skills that are learnt throughout work and life to your job.

The statements below list the typical employability skills that would be applied in a situation related to managing a production system within a forestry enterprise. In completing your daily work tasks, activities and assessments related to this resource, you must be able to demonstrate that you are applying the following skills:

- Technical skills to select sampling techniques and create sampling designs; identify species growing in the target area; and identify components of the forest/plantation that contain carbon stocks
- Communication skills to use appropriate consultative, communication and interpersonal techniques with colleagues and others; and present written and oral information to a wide range of individuals and groups
- Literacy skills to analyse qualitative and quantitative information and data; prepare site maps and plans; and accurately prepare a range of reports, documents and submissions where precise meaning is required
- Numeracy skills to use models to predict growth; and use and adapt complex maps and diagrams
- Problem-solving skills to demonstrate time and project management.

HOW THE SKILLS LEARNED APPLY TO YOUR WORKPLACE

This resource describes the outcomes required to assess forests and plantations for current and future carbon stocks, including the use of growth modelling techniques.

The content covers assessing forests and plantations for current and future carbon stocks in a variety of work settings, including:

- Native forests
- Hardwood or softwood plantations
- Agroforestry and farm forestry plantations.

The skills and knowledge required for competent workplace performance are to be used within the scope of the person's job and authority.

1. DEVELOP A CARBON STOCK SAMPLING PLAN

LEARNING OBJECTIVES FOR THIS SECTION

At the completion of this Section, students should be able to:

- Describe the Work health and safety (OHS), environmental, legislative and organisational requirements that are applicable to a carbon sampling requirement
- Assess existing conditions of the forest, and how these impact on design of a forest carbon sampling program
- Design a forest carbon sampling program to meet the objectives of the program or implementing organisation

INTRODUCTION

Through the process of photosynthesis, trees and other vegetation remove Carbon Dioxide (CO_2) from the atmosphere and store it in plant tissue, such as the trunk, leaves, branches and roots. The total amount of carbon stored within a forest is referred to as the forest's 'carbon stock'. The carbon stock of a forest is directly related to the weight of a tree and other components of the forest. Therefore, if we measure the weight of a tree or other forest components, we can determine the amount of CO_2 they have removed from the atmosphere. The basic principle that forest carbon stock is proportion of the weight of forest components forms the foundation of all forest carbon sampling programs.

This Unit describes how to plan and implement a sampling program that will allow forest managers to estimate the quantity of carbon stored in the trees (above and below ground), other vegetation, litter layer, soil, and wood products. The Unit focuses mostly on procedures for measurement of tree biomass, from which the principles can be transferred over to the other carbon pools.

WHAT IS FOREST CARBON STOCK SAMPLING?

When estimating the amount of carbon stored in a forest, it is not usually practical to measure all trees in the forest. Therefore forest carbon stock is estimated by implementing a forest carbon stock *sampling* program. This involves taking a series of pre-defined carbon stock measurements in a small sub-set of the forest or plantation area, and using these to estimate carbon stock for the whole forest or plantation. Measurements are typically taken from geographically defined sampling units, which are commonly known as 'plots'. Careful planning will help maximize the efficiency of the forest carbon sampling process, as described in this section.

IDENTIFY APPLICABLE LEGISLATION AND REGULATION

At the time of writing, there are no legal requirements prior to implementing a carbon sampling program for forests in Australia. However if you choose to undertake carbon sampling in a forest, you will need to follow all the same WH&S, environmental, legislative and organisational requirements that apply to any forest operation.

Some of these legislative requirements are applied at Federal level, while others vary across States/Territories.

Activity 1.1

1. Access the Safework Australia website: http://www.safeworkaustralia.gov.au/. Explore the Section related to 'Model Work Health and Safety Laws'. http://www.safeworkaustralia.gov.au/sites/swa/model-whs-laws/pages/model-whs-laws[1]

   What are the Model Codes of Practice? Are there any Model Codes of Practice that you think are relevant to implementation of a forest carbon sampling program?

2. Access the Safework Australia 'Guide to Growing and Managing Forests' (http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/844/Growing-managing-forests.pdf).[2]

   What are the main WH&S risks you think could be associated with conducting a forest carbon sampling program?

3. Navigate to the website of the WH&S regulator in your State/Territory, by following the links from the Safework Australia homepage (http://www.safeworkaustralia.gov.au/sites/SWA). Once you have entered the website applicable for your State or Territory, type the word 'forest' in the search box. What WH&S codes and legislation do you think are applicable to conducting a forest carbon sampling program in your State or Territory?

4. Environmental legislation related to forests is typically administered at State or Territory level. Search the web for the terms 'Environment Department [YOUR STATE OR TERRITORY]'. Once you have navigated to the Environmental Department for you State or Territory, explore the website to determine the key legislation governing environmental management. What are the three main Acts or Regulations that impact on forest management in your State or Territory? What are the objectives of these Acts or Regulations?

1 Weblink accessed on 25 May 2014.

2 Weblink accessed on 25 May 2014.

DEFINE THE OBJECTIVES

There are numerous reasons that forest managers may need to measure and forecast the quantity of forest carbon in their forests. A thorough analysis of why the sampling program is to be conducted should be undertaken prior to defining its scope of the sampling program. Refining the purpose and objectives of the carbon sampling program will require discussions with stakeholders. These might be: investors, land holders, property managers, local communities, customers, or special interest groups such as environmental NGOs.

The following guiding questions could be used as part of the stakeholder discussion and analysis of the sampling purpose and objectives:

- What will the results of the survey be used for?
- How accurate does the carbon estimate have to be?
- Will the results be audited by a third party?
- How much money is available for the sampling program?

Examples of commonly cited purposes and objectives for forest carbon sampling are provided in Table 1 below.

Table 1: Examples of some commonly cited purposes and objectives for forest carbon sampling programs

Purpose	Objectives
To generate and sell carbon credits under the Australian Government's Carbon Farming Initiative (CFI)	• To measure forest carbon stocks in accordance with an approved methodology under the CFI, to achieve a required error limit and confidence level as determined by the methodology • To forecast carbon stock changes in order to submit tender documents under the proposed Emissions Reduction Fund (ERF) • To monitor and report carbon stock changes under the CFI, in response to forest growth or a disturbance event • To assess the feasibility of applying a CFI methodology
To sell carbon on the voluntary carbon market	• To achieve compliance against the National Carbon Offset Standard (NCOS), Verified Carbon Standard (VCS), or other third party carbon standard • To demonstrate clear and transparent carbon accounting procedures to potential buyers of carbon
To achieve certification to the Australian Forestry Standard (AFS) or the Forest Stewardship Council (FSC) standard	• To maintain, enhance and/or report the level of forest carbon stock in order to meet the requirements of the certification standard • To generate a quantitative estimate of the current and future carbon storage on the forest area to be certified
To report the greenhouse balance of a forestry investment to shareholders or other stakeholders	• To achieve carbon neutrality by 2020 through increased carbon sequestered in a plantation estate • To become one of the top 40 companies listed on Australia's SAM sustainability index (AuSSi).[3] • To report the carbon footprint of the organisation to the Carbon Disclosure Project

3 The Australian SAM Sustainability Index (AuSSI) is a stock market index, whereby companies are ranked in terms of their corporate social responsibility. The AuSSI represents the aggregated stock performance of the leading 10% of companies in industry sector.

To meet the recommended reporting requirements of the Australian Securities Exchange (ASX)	• To adhere to ASX Principle 3 to "act ethically and responsibly", which includes a requirement "to act responsibly towards the environment" • To adhere to ASX recommendation 7.4 where "a listed entity should disclose whether it has any material exposure to economic, environmental and social sustainability risks and, if it does, how it manages or intends to manage those risks"
To obtain knowledge about carbon stocks stored in forests for research or policy-development purposes	• To obtain a statistically significant estimate of the impact of forest management interventions (such as thinning, burning or harvesting) on carbon stock of the forest • To determine the contribution of Australia's forests towards meeting Australia's Greenhouse Gas reduction targets

Activity 1.2

1. Review the ASX Corporate Governance Principles and Recommendations (http://www.asx.com.au/documents/asx-compliance/cgc-principles-and-recommendations-3rd-edn.pdf). [4]

   What do you think are some of the advantages and disadvantages of reporting carbon stocks for a publicly listed forestry company? List your reasons.

In many cases it is likely that the carbon sampling program will be conducted alongside forest assessment for other purposes, such as:

- Assessment of timber volumes
- Biodiversity assessment
- High Conservation Value Forest assessments
- Cultural assessments
- Non-timber forest products and services

In cases where the carbon sampling is being conducted alongside other assessments, the purpose and objectives of the carbon sampling will need to be reflective of the multi-purpose sampling.

4 Linked access on 25 May 2014

DEFINE THE SCOPE OF THE SAMPLING PROGRAM

Once the purpose and objectives of the sampling program have been determined, the scope or 'boundaries' of the carbon sampling program can be defined. The following sampling boundaries will need to be considered in the sampling design:

- Organisational – e.g. sample all forests owned by the parent company, or only those that are owned by a specific subsidiary?
- Geographic – e.g. sample all forests on a particular site or region, or all forests that are located in your State/Territory, or Australia-wide?
- Temporal – e.g. produce a one-off upfront estimate of carbon stock, or ongoing series of periodic measurements?
- Operational – e.g. sample all non-harvestable areas set aside for environmental or social reasons, or the entire forest estate?
- Compliance and efficiency considerations – e.g. sample only those areas that are eligible under a specified carbon standard or program such as the CFI, or sample the whole forest? Sample only those carbon pools that are required to achieve compliance with a specific standard, or sample all carbon pools?

If the carbon sampling program is being undertaken for the purposes of compliance with a particular carbon standard or carbon market, then the boundaries of the sampling program must meet the requirements of that standard or market. Many carbon programs have very specific dates and eligibility requirements that define areas that are eligible to generate carbon credits, as well as exclusion zones. To avoid wasting money and time, the eligibility of the forest should be assessed prior to sampling, and ineligible areas should be excluded (unless they are being sampled for another purpose). Table 2 below provides examples of dates and eligibility requirements under the CFI which will impact on carbon stock sampling boundaries.[5]

Table 2: Examples of eligibility requirements that may affect sampling boundaries for projects implemented under the CFI

Eligibility requirement	Source	Implication for Sampling Boundaries
Definition of 'forest', being: "land of a minimum area of 0.2 hectares on which trees (a) have attained, or have the potential to attain, a crown cover of at least 20% across the area of land; and (b) have reached, or have the potential to reach, a height of at least 2 metres."	CFI Regulations	Areas that do not meet this definition of 'forest' will need to be excluded from the carbon sampling boundaries
Methodology eligibility requirement for Reforestation/Afforestation: Permanent planting [must be] established on or after 1 July 2007	CFI Methodology for Reforestation and Afforestation	Permanent plantings established before 1 July 2007 may not be eligible, and therefore these areas may be excluded from the sampling boundaries, unless it can be demonstrated that the plantings were established for carbon purposes

5 Dates and eligibility requirements are examples only, and are subject to change. Information is correct at the time of writing (May 2014). To ensure materials are up to date, users of this training material should access the most recent information on the Department of Environment website: http://www.environment.gov.au/

Methodology eligibility requirement for Reforestation/Afforestation: For at least 5 years before project commencement, the project area must have included: (a) land used for grazing or cropping; or (b) land that was fallow between grazing or cropping activities	CFI Methodology for Reforestation and Afforestation	Areas that do not meet these requirements for the 5 years prior to project commencement may need to be excluded from the sampling boundaries
Methodology eligibility requirement for Native Forest Protection (avoided deforestation): The project area must include native forest: (a) that was native forest on 31 December 1989; (b) that was native forest at all times between 1 January 1990 and project commencement; (c) for which there is clearing consent that was issued before 1 July 2010	CFI Methodology for Native Forest Protection	A time series of satellite images or aerial photographs, as well as copies of legal clearing consents, should be obtained in order to delineate which areas meet these eligibility requirements.
Methodology eligibility requirement for Native Regeneration: The project area must include land that has been subject to the suppression activity such that the land did not achieve forest cover in the baseline period (i.e. the 10 year period prior to project commencement)	CFI Methodology for Human-Induced Regeneration of a Permanent Even-Aged Native Forest	A time series of satellite images or aerial photographs should be obtained in order to delineate which areas meet these eligibility requirements.
Methodology eligibility requirement for Native Regeneration: Project Commencement begins on a date, on or after 1 July 2007, for which there is documentary evidence that forest suppression activities in the project area have ceased or will cease and a human assisted regeneration activity will commence.	CFI Methodology for Human-Induced Regeneration of a Permanent Even-Aged Native Forest	Sampling boundaries may be defined by areas in which a documented decision to cease suppression activities has been made (for example, a decision not to engage a clearing contractor), and to commence regeneration activities (for example, removal of livestock).

Activity 1.3

1. Review the eligibility requirements in Section 2.3 of the Native Forest Protection (avoided deforestation) methodology, available at: http://www.comlaw.gov.au/Details/F2013L01181.[6] What are the eligibility requirements for this methodology?

6 Accessed 25 May 2014

COLLATE INFORMATION ABOUT THE FOREST AREA

Before designing the carbon sampling program, it is necessary to have a good understanding of the characteristics of the area to be sampled. This can be obtained as a result of an initial field reconnaissance, and/or on a desktop basis using existing reports, maps, remotely sensed imagery, photographs, GIS datasets, or anecdotal information from persons familiar with the forest area. The type of information or observations that might typically be collected include:

- Property boundaries
- Species or forest types present
- Data from previous forest sampling programs
- Location of non-forest areas
- Geographic features such as roads, access points, waterways, buildings etc
- Topographical features such as slope, aspect
- Management and disturbance history
- Location of hazards
- Sensitive environments such as protected areas or riparian zones

The information collected at this stage will be invaluable in informing decisions related to design of the carbon sampling program, as discussed in the next Section.

Assessment 1

The purpose is to conduct a desktop assessment of information related to a forest area nearby, to be used as the basis of a carbon sampling design. This exercise shows how various different types of information can be collected, and how these can be used to make carbon sampling design decisions. The results should be prepared in a short summary report.

1. Choose a forest area nearby, preferably one that has a reasonable level of published information about it (such as a National or State park).

2. Use Google Earth to explore the forest area. Google Earth is a tool that can be very useful in obtaining an overview of the characteristics of most places on earth. The software can be downloaded free of charge at: http://www.google.com/earth/explore/products/ .[7] Use the Google Earth controls to explore the forest area. Click on the options on the left hand side to display Borders and Labels, Places, Photos, and Roads. Use the measure tool to determine the area of the forest, and length of the forest perimeter. Save an image of the forest area to put in the report.

7 Accessed 25 May 2014

3. Use the internet to search for existing publications about the forest area. In particular, try using Google Scholar (http://scholar.google.com.au/), or resources from the website of your State/Territory Environment Department. Specifically, try to find information about previous vegetation assessments, management history, management objectives, and information about access or infrastructure in the forest.
4. There is a wealth of geographical information that can be obtained about a forest area. For example see: • Forest maps and tools produced by DAFF: http://www.daff.gov.au/abares/forestsaustralia/Pages/forest-maps-and-tools.aspx; • The National Vegetation Information System (http://www.environment.gov.au/topics/science-and-research/databases-and-maps/national-vegetation-information-system); • Mapping products provided by the State-based environmental agencies. For example, the 'Biodiversity Interactive Map' hosted by Victoria's Department of Environment and Primary Industries (http://mapshare2.dse.vic.gov.au/MapShare2EXT/imf.jsp?site=bim). • Geoscience Australia 'Discover Information Geographically' website (http://www.environment.gov.au/metadataexplorer/explorer.jsp). • Note that spatial data from the GeoScience Australia website can be viewed on ArcGIS. If you or someone in your organisation does not have a copy of ArcGIS, then this spatial data can be viewed free on ArcGIS Explorer (http://www.esri.com/software/arcgis/explorer).
5. Use the information collected in steps 1 – 4 above to prepare a report summarising the following aspects of the forest, and explain how these features might impact on design of the sampling program: • Management objectives • Species or forest types present • Data from previous forest sampling programs • Location of non-forest areas • Geographic features such as roads, access points, waterways, buildings etc • Topographical features such as slope, aspect • Management and disturbance history; • Location of hazards • Sensitive environments such as protected areas or riparian zones

DESIGN THE CARBON SAMPLING PROGRAM

Design of a forest carbon sampling program should include four main steps:

1. Choose a sampling strategy
2. Decide which carbon pools to measure
3. Determine the number, type, and size of sampling plots
4. Determine the frequency of measurement.

A more detailed description of each of these steps is provided below.

Step 1: Choose a sampling strategy

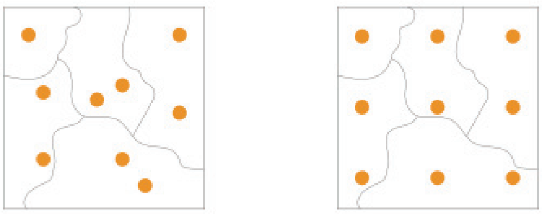
There is a number of different methods or sampling strategies that may be adopted for forest carbon sampling. The most commonly adopted methods are: 1) complete measurement; 2) simple random sampling; 3) systematic sampling; 4) stratified sampling; 5) cluster sampling; 6) point sampling; and 7) multi-phase sampling. These sampling types are described below. They mainly focus on sampling of trees, although the sampling principles remain the same for sampling of soil, litter and dead wood.

Complete measurement involves measuring every tree within the forest. This sampling design may be appropriate for small forest areas such as agroforestry plantings. However for commercial forests, it is generally considered an inefficient design, as measuring every tree in the forest would take too long, and the cost would be too high.

Simple random sampling involves measurement of sampling units (such as a tree or plot) allocated randomly across the forest area, such that every sampling unit in the forest has the same probability of being sampled. For example, every tree in the forest might be numbered, and the trees for measurement could be selected using a random number generator.[8] The benefit of this design is there is no bias, and it is very simple to calculate the population statistics. However it is generally not the most efficient design where the forest has notable variation within it. Therefore this design might be limited to homogenous stands such as a single-age plantation on a site with little slope or soil variation.

Systematic sampling involves measuring plots at regularly spaced intervals. For example, it might involve establishing a plot at every 1km intersection, using a square grid overlaid on the forest area (Figure 1). It could also involve establishing a plot every 1km along a transect line. A systematic sample ensures an even spread of measurements across the sampling area. This is useful if there is little prior information known about the forest. Systematic sampling is also useful where travel between plots is difficult, such as forest with thick undergrowth. Note that this approach can be combined with stratified sampling (see below) if there is prior knowledge about the varying strata that might be present onsite.

Figure 1: Random (left panel) vs systematic (right panel) location of plots

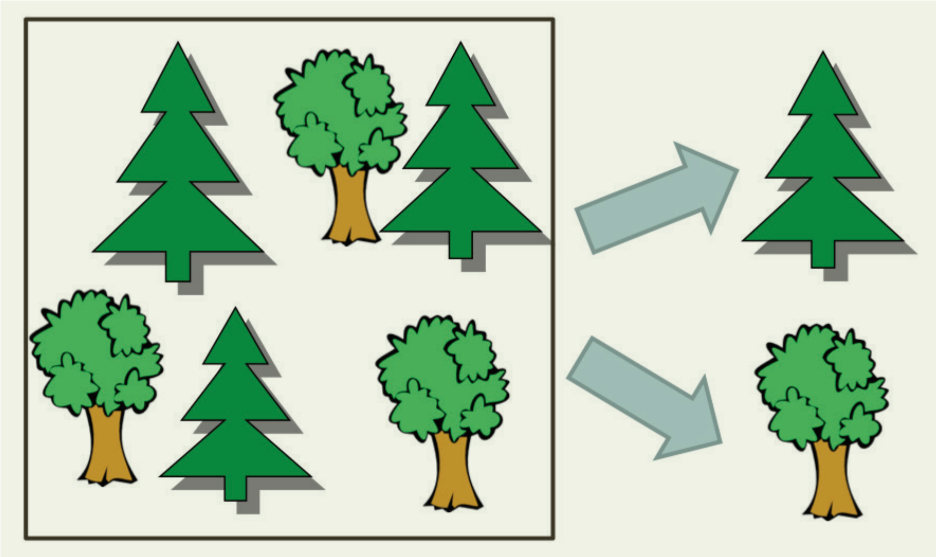


Source: IPCC (2013) *In*: IGES (2014)

Stratified sampling involves defining a forest 'stratification' system, and then establishing a target number of plots within each defined stratum (allocated on either a random or systematic basis). 'Stratification' is the process of grouping a forest into areas with similar characteristics (Figure 2). This process is intended to improve the efficiency of the sampling program, as variation within a stratum is minimised, making it more likely that the measurements taken in the sub-sample are representative of the entire stratum. This provides a better (more precise) estimate of the average carbon stocks for the stratum generated with the least amount of effort and cost.

8 For example, by entering the '=RANDBETEWEEN(1, [Max tree no.])' function into MS Excel, or using a pseudo-random number generator with a known seed number, in ArcGIS.

Figure 2: Forest stratification involves grouping the forest into areas with similar characteristics



The aim of stratification for carbon sampling is to group the forest into areas that are likely to have similar carbon stock, or change in carbon stock. As such, the strata might be defined by vegetation type (e.g. eucalypt open forest), soil type (e.g. sandy loam), topography (e.g. alpine areas), or management activities (e.g. planted in 2003 and thinned in 2013). Field observations or existing data about the forest can be used to determine which biophysical aspect to use as the basis for the stratification system. For example, if there is a change in soil type in the forest, and it is observed that the soil transition is associated with a noticeable difference in tree size, then stratification on the basis of soil type is recommended. The most common way to stratify a native forest for carbon sampling is by forest type. The most common way to stratify a plantation is by planting year.

The output from the stratified sampling program typically will be an estimate of average carbon stock for each stratum. The carbon stock of all strata in the forest is then summed to provide a carbon stock estimate for the whole forest. In cases where the forest composition is similar (for example, a plantation established in the same year), there might only be one stratum (e.g. Radiata pine plantation, established in 2000).

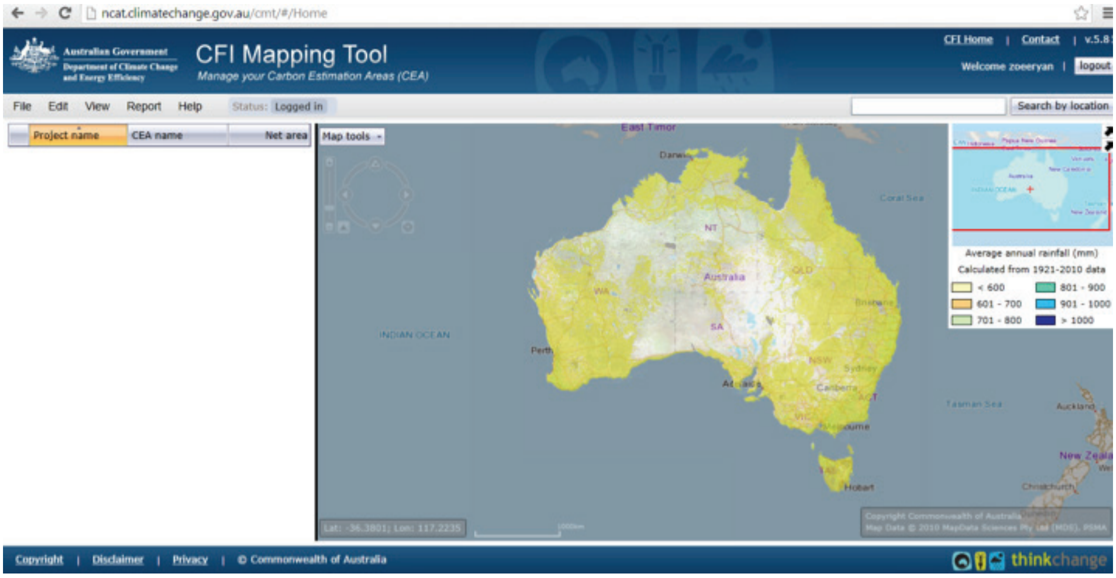
Activity 1.4

1. Use information collected in Assessment 1 to recommend a forest stratification system for this forest. What is the basis of your forest stratification system? Explain your choice. How is your forest stratification system related to the carbon stock of this forest?
2. Prepare a map of this forest area using the method of your choice (e.g. Google Earth, ArcGIS, Mapping products from State-based agencies).

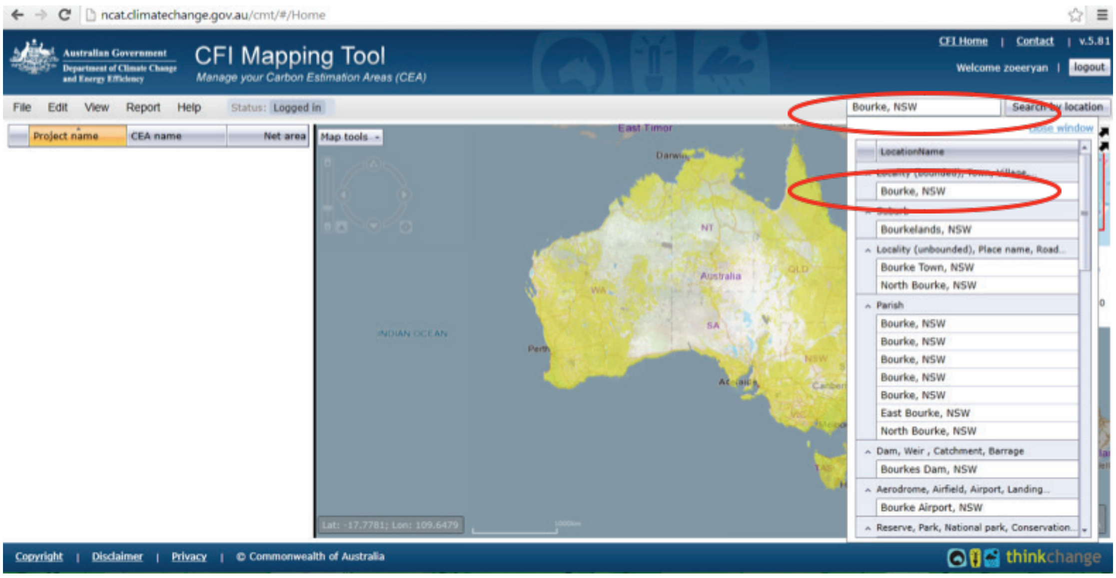
Assessment 2

In this Assessment Task, the Australian Government's CFI Mapping Tool will be used to: Create a 'Carbon Estimation Area' (CEA), which is essentially a geographically defined CFI stratum or Project Area; 2) to determine the area of the CEA that existed on 31 December 1989, as is required under the Native Forest Protection (avoided deforestation) methodology mentioned in Activity 1.3 above; and 3) to create a model point location, which can be used for carbon modelling using one of the Government's carbon modelling tools. This will require the user to obtain a login for the 'Reforestation Tools' website: http://ncat.climatechange.gov.au/cfirefor/,[9] by following the instructions on the website. Once logged in:

1. Navigate to the CFI Mapping Tool (click on the 'CMT' tab at the top of the page). A map of Australia will appear.

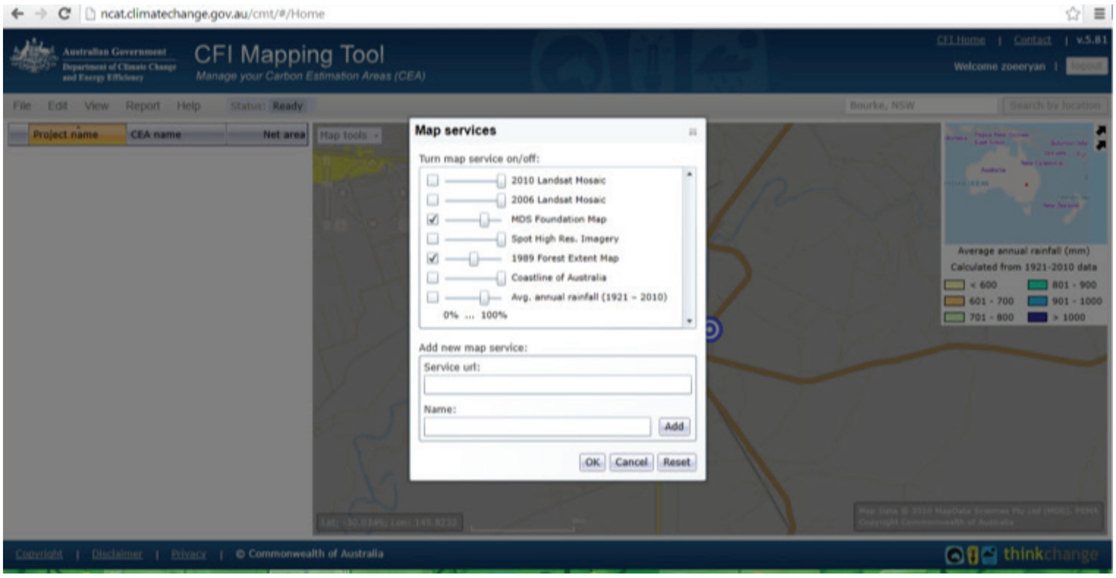


2. Click in the 'Search by Location' box in the upper right hand side. Type in 'Bourke, NSW' and click on 'Search by Location' box, as shown in the image below. A dropdown list of references relating to the town of Bourke will appear. Double click on the first option, which is for the locality of Bourke, NSW.

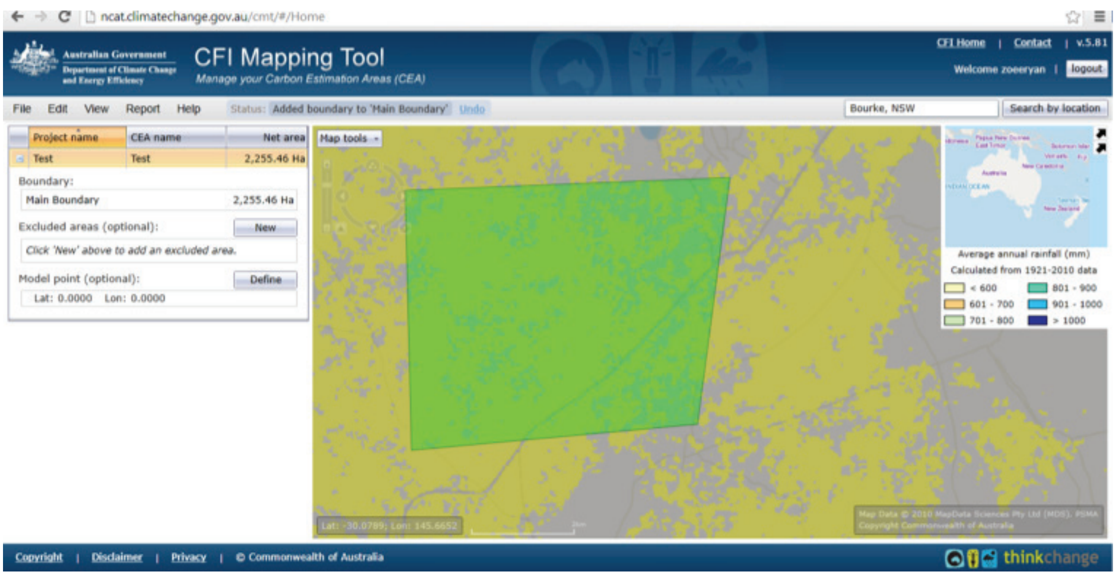


9 Accessed 25 May 2014

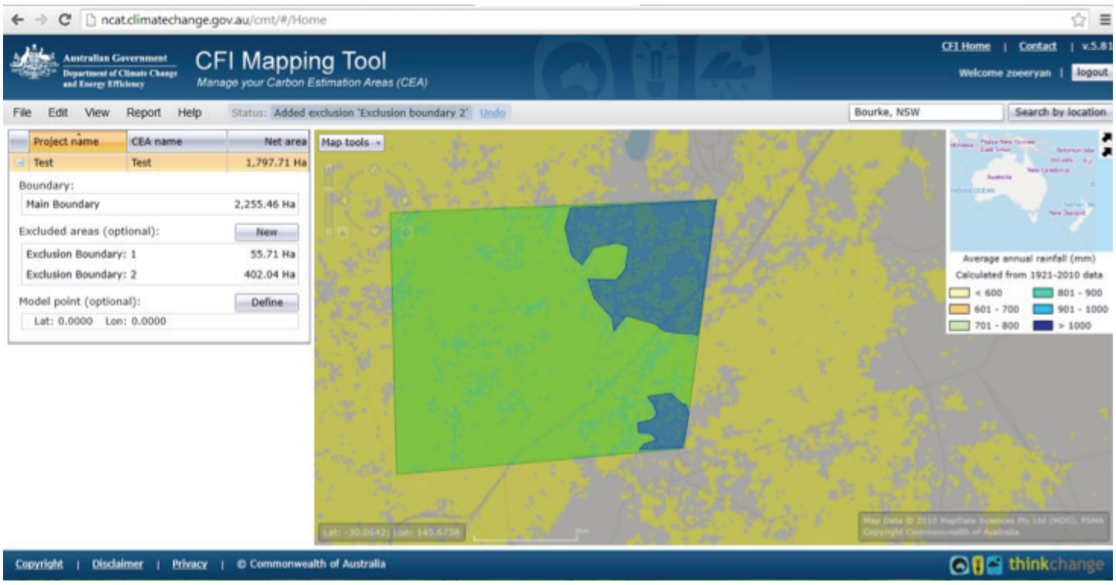
3. The map will zoom in on the town of Bourke, in NSW. Click on the 'Map Tools' dropdown box in the left of the map, then click on 'Data layers'. Unclick the '2006 Landsat Mosaic' option so that only the 1989 Forest Extent Layer and the MDS Foundation Map will display. Click 'Ok'. The 1989 Forest Extent layer will now display (i.e. the areas shaded yellow).



4. To create a new Carbon Estimation Area (CEA), click on the 'Edit' tab, and select 'Add new CEA'. A dialog box will appear, requesting a name for the CEA and Project. Provide appropriate names in these sections, then click 'Add and create boundary'. Zoom out and choose an area approximately 30 km west of Bourke (tip: using the 'measure' tool will help with this). Now click on 'New' in the left hand side and follow the instructions to create a polygon of your preferred size.



5. To distinguish the areas that contained forest on 31 December 1989 (i.e. areas that are eligible to generate credits under the native forest project methodology), it is necessary create a number of 'exclusion areas' (to remove areas that did not contain forest in 1989). These are the areas coloured grey on the map. Click on the 'New' box in the left hand side and follow the instructions to create an exclusion area to remove ineligible (non-forest) areas from your CEA. Keep adding exclusion areas until ineligible areas have been removed from the CEA.



6. What is the total 'eligible' area within your CEA? What is the total exclusion area?

7. To determine the latitude and longitude of a 'model point' location in your CEA (which can be used to estimate carbon stock using one of the Government forest carbon models), click on the 'Define' button, and click on an eligible area somewhere in your CEA. The latitude and longitude of this point will be displayed in decimal degrees. Write this down.

8. Click 'save', saving your CEA as a shapefile. Explore other aspects of the CFI Mapping Tool, and then close the program. Provide a copy your CEA shapefile to your assessor, as well as answers to each of the questions in this Assessment Task.

Cluster sampling involves the co-location of a number of plots relatively close to each other. This method is commonly used where there is long or difficult travel time between plots, as the field crew can quickly measure the cluster of plots without wasting too much time in travelling between them. The pattern of clustered plots should be pre-defined, for example a cluster of four plots aligned along the compass meridians. Care should be taken to estimate statistics using cluster means, not the values observed on individual plots. The sampling design should also ensure that all plots within a cluster are located within a single stratum.

Point sampling involves measurement of trees around a point, rather than establishment of a plot. From the fixed point, trees will be selected for measurement if they exceed a specific size threshold. The technique requires the use of an object of known size, which is compared to the tree diameter to determine if the tree will be measured or not. Equipment as simple as the surveyors thumb or a stick can be used for this purpose. Alternatively, pre-calibrated equipment such as factor gauge, prism wedge, or relaskop also can be used. An in-depth discussion of point sampling techniques is beyond the scope of this document, but more information can be obtained from the references cited at the back.

Multi-phase sampling involves undertaking sampling in more than one stage, whereby the intensity of sampling increases with each successive stage. The first stage of sampling will involve sampling within large sized units (for example, sampling forest and non-forest areas). Once the first stage has been completed, the sampling can then narrow in on smaller sub-units of interest (for example, sampling only riparian areas within the forest). The main advantage of multi-phase sampling is that it concentrates sampling effort on the area of interest, thereby minimising cost and effort. An in-depth discussion of multi-phase sampling techniques is beyond the scope of this document, but more information can be obtained from the references cited at the back.

Step 2: Decide which carbon pools to measure

The Intergovernmental Panel on Climate Change (IPCC) has defined a broad carbon accounting framework that provides the basis for most forest carbon sampling programs. The IPCC defines six main 'carbon pools' or stocks which can be included in a forest carbon sampling program. These are:

1. Aboveground biomass, which can be divided into tree and non-tree pools (e.g. shrubs etc)
2. Belowground biomass (i.e. tree roots)
3. Soil organic matter
4. Dead wood (including debris such as fallen branches and logging residues)
5. Litter (i.e. fallen leaves)
6. Wood products

Not all of these carbon pools must be sampled at all times. In order to make the most efficient use of available resources, generally only those pools considered to be 'key categories' are included within the sampling program. 'Key categories' refer to the carbon pools and activities that have the greatest contribution to either the absolute level, the trend (i.e. the change in carbon stocks), or the uncertainty in the amount of carbon sequestered/stored. If a pool is considered not to be a key category, it is generally good practice to justify why a carbon pool is excluded from sampling.

The general approach to defining key categories is to:

- Conduct a desktop-based assessment of the likely change in carbon stocks for each pool over the analysis period. This can be done by examining 'default values' in journal papers and other resources, or by examining carbon inventories prepared for similar forestry activities
- Prepare a table, listing the expected carbon stock change from each pool in descending order of magnitude
- Choose those pools that make up to 95% of the total carbon stock change anticipated over the analysis period.

If it is not possible to conduct a detailed key category analysis, the following 'rules of thumb' can be used as guidance for decisions about which carbon pools to measure:

- Aboveground tree biomass is almost always considered a key category for forestry projects.
- Soil carbon is expensive to measure, so it is generally only included if the soil carbon stock is likely to be depleted by the forestry activity. For example, if the soil will be disturbed (e.g. ploughed). It is also often measured if the forest area is a wetland.
- The dead wood pool is generally included in sampling programs if timber harvesting will take place. This is because logging slash will result in a significant increase in the dead wood carbon stock, making it likely to be a 'key category' after timber harvesting occurs.
- Litter generally accounts for about 4–5 % of total aboveground carbon stocks, so whether it should be included in the sampling program is generally dependent on the forest type (i.e. litter should be included in forest types that produce large quantities of dead leaves). Litter is also included where required for ecological study purposes (for example, to better understand nutrient cycling processes in the forest), or if the purpose of the carbon sampling is to determine the impact of a fire.
- Where timber harvesting takes place, the carbon stock of the wood products pool will increase over time. As a result, many forestry and forest products companies like to include the wood products pool in a carbon sampling program if possible, as its inclusion typically results in a 'positive' greenhouse balance for the sector.

Activity 1.5

1. Go to the website for the Clean Development Mechanism (http://cdm.unfccc.int/). Search the website using the terms 'Project Design Document' and the Project titled 'Reforestation of grazing Lands in Santo Domingo, Argentina', implemented under the Clean Development Mechanism (CDM). Refer to Section C.3 of the document. Which carbon pools are included in the sampling? Which carbon pools are excluded? What justification is provided for not measuring the excluded pools?

2. Access the Verified Carbon Standard (VCS) Project Database: http://www.vcsprojectdatabase.org/. Search for projects with the sectoral scope 'Agriculture, Forestry and Other Land Use' (AFOLU). Click on one of the AFOLU projects of your choice and review its 'Project Document'. Which carbon pools are included in the sampling? Which carbon pools are excluded? What justification is provided for not measuring the excluded pools?

Step 3: Determine the type, number and location of sampling plots

Typically, the two main objectives when choosing a forest carbon sampling type are: minimisation of **bias**; and maximisation of **efficiency**.

'Bias' in the context of forest sampling refers to the systematic over- or under-representation of certain aspects of the population in a sample. Put simply, bias means overemphasising particular components of the forest. An example of bias might be only sampling forest areas with good growth, or locating all sample plots within 50 metres of a road. 'Efficiency' refers to the process of achieving the best possible estimate of carbon stock, for the least amount of effort/cost, and with a known level of uncertainty. In this case, 'best' is defined by how close the estimate of forest carbon stock is to the reality, otherwise known as the 'accuracy' of the estimate. A forest carbon sampling program should aim to be as accurate and precise as possible (Figure 3).

Figure 3 Schematic diagram explaining the difference between precision and accuracy

With these considerations in mind, the forest manager will need to decide the number, type, and size of sample plots, as described below.

Number of plots

Note that calculation of the number of plots requires some understanding of population statistics. Note that an in-depth discussion of sampling statistics is considered beyond the scope of this document. Further information about sampling statistics can be obtained from the recommended reference material. Otherwise, it is recommended that a sampling specialist be consulted in order to assist with the statistical aspects of sampling design. Nevertheless, a brief overview of the procedures for selection of the required plot number is provided below.

The number of plots to be measured is determined by two factors: 1) the level of precision required from the carbon sampling; and 2) the variability of the population or strata. Generally, the higher the level of precision required (known as 'target precision'), the more plots that must be measured, and the higher the cost of the sampling. If the forest or stratum is highly variable, then more plots will be required to achieve target precision than if the forest was more homogenous.

Many carbon market standards will specify the target precision required to achieve compliance with the program or methodology. Target precision is usually expressed in terms of the size of the standard error (or variability), relative to the mean (i.e. 'average'). For example, a standard error that is within 10% of the mean is a commonly used target precision under the CFI.

The number of plots required to achieve target precision can be estimated upfront, based on the results of a pilot sample. This involves taking a preliminary sample of approximately 6 – 10 plots (for a plantation), or around 15 plots (for a native forest), in order to develop a quick estimate of the mean forest carbon stock and associated standard deviation. This information can then be input to an equation in order to estimate the required plot number. The more accurate is this initial estimate, the more efficient the final carbon sample will be. In practice, most people now use a calculator or excel spreadsheet in order to determine the number of plots. An example is the 'Winrock Sampling Calculator' (http://www.winrock.org/resources/winrock-sample-plot-calculator).[10]

10 Accessed 31 May 2014

Activity 1.6

1. Use the Winrock Sample Plot Calculator to calculate the required number of sampling plots for a forest sampling program with the following attributes:
   - A target error of 10% at the 90% Confidence Level.
   - Two strata: *Eucalyptus* open forest (100 ha), and *Callitris* woodland (50 ha).
   - Based on the pilot survey, the following results were calculated: *Eucalyptus* Open Forest: mean biomass of 120 tonnes (t) of dry matter (dm) per hectare (ha^{-1}); Standard Deviation of 40 t dm ha^{-1}; *Callitris* woodland: mean biomass of 80 t dm ha^{-1}; Standard Deviation of 15 t dm ha^{-1}.
   - Plot size of 0.02 ha.

How many plots are needed in the *Eucalyptus* Open Forest strata, in order to achieve the required sampling precision? How many for the *Callitris* strata?

2. Explain why there is such a large difference in the required plot number between the two strata.

3. It is good practice to measure slightly more plots than is required to achieve the target precision. This allows a buffer, in case of errors during the sampling. How many plots should be measured for each stratum, assuming a 5% buffer for error?

4. What happens to the required plot number if you increase or decrease the target precision? And what happens when you adjust the confidence level? Explain your results.

5. What happens if you increase the standard deviation of your pilot sample? Explain your results.

Assessment 3

1. Use the Winrock Sample Plot Calculator to determine whether a single or multiple strata provides a more efficient sampling design. For the same forest described for Activity 1.6 above:

- Assume that the two strata: *Eucalyptus* open forest (100 ha), and *Callitris* woodland (50 ha), are merged to form a single strata, titled 'native forest' (150 ha). This can be listed in the 'stratum 3' row of the calculator.
- Calculate the mean biomass for the combined strata, based on the combined average biomass for the two strata. Also assume that that standard deviation is the average of the two strata.
- Assume a plot size of 0.02 ha, and a target error of 10% at the 90% Confidence Level.

How many plots are needed for this combined strata, in order to achieve the required sampling precision? How does this compare to the total number of plots required, when there are two separate strata? Does having multiple strata increase or decrease the efficiency of this sampling program?

2. Create a number of new strata, assigning them a range of mean biomass and standard deviations.[11] Compare the required plot number to the 'native forest' strata, assuming all strata are merged using average values. Prepare a short report summarising in what cases a stratification system increases the efficiency of the sampling system (measured in terms of required plot number), compared to when it is best just to assume a single strataum.

Type of plot (permanent, temporary)

A forest sampling 'plot' is a defined geographic area in which the sampling measurements will be taken. Plots can either be 'permanent' or 'temporary'. Permanent plots are designed to be re-measured periodically (e.g., every five years). They are typically used if the forest manager is interested in measuring tree growth or carbon stock changes over time (for example due to forest growth or disturbance). One drawback of permanent plots is that they can receive 'special treatment' if marked conspicuously (for example, they might be excluded from a silvicultural operation). Therefore it is good practice to establish permanent plots with markers that are not obviously visible to the human eye. Temporary plots are often used in commercial timber inventories. They are typically quicker and easier to set up, and they allow the stratum boundaries or sampling intensity to be adjusted over time. However measurement data from these plots are less accurate when attempting to measure changes in carbon stock, as different trees will be measured in each successive sample period.

Plot size

Choices around the size and shape of the plot have a significant influence on the efficiency of the sampling program. In determining the plot size, the inventory manager should aim to minimise the variation between plots (i.e. the average carbon stock of each plot should be as similar as possible). Plot size has trade-offs in terms

11 To provide an idea of the range of biomass values typically observed in forests and plantations, refer to Tables 4.7 and 4.8 in Chapter 4, Volume 4 of the 2006 IPCC Guidelines: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf.

of the total number of plots that can be measured for a given budget. In other words, the larger the plot, the more time spent in measuring each plot, the fewer plots that can be measured. Therefore the inventory manager needs to be sure that any increase in plot size achieves a commensurate reduction in variability between plots. As a rule of thumb, the plot size should be sufficient to measure between 10–20 trees per plot, in order to obtain a representative sample. In addition, where the forest is 'patchy' or has high variability, a larger plot size should capture this variation within the plot itself. For example, a 0.5 hectare size plot (e.g. with dimensions 100m x 50m) should be large enough to include sufficient density of larger diameter trees, as well as any gaps in the forest. If the plot size was too small (say, 0.1ha or 10 x 10m), it may fall entirely within a 'gap' in the forest, which would result in a very low carbon stock being reported for the plot. This would increase the variability among plots, requiring increased sampling effort to achieve the target precision. In native forests, large trees tend to occur more infrequently than smaller trees. As a result, a larger plot size is typically required in order to capture a representative sample. To give an idea of the range in plot sizes, measurement of seedlings might only require a plot size of a few square metres, while mature native forests might be sampled with a plot size of between 0.01–1 hectare.

Regardless of the plot size chosen, the area of the plots should be kept consistent throughout the inventory. If there is a change in the plot size over the course of the inventory, this should be documented in the Standard Operating Procedures.

Adjustments for plot size may need to be made where the slope exceeds a certain threshold. This is because the geographical area of a sloped plot will exceed the mapped area of a plot (which assumes a horizontal plane). This adjustment can be made in the field (i.e. by requiring the field crew to hold the measuring tape horizontal when laying out plot boundaries), or on a desktop basis after completion of the inventory (i.e by calculation of plot dimensions through application of trigonometry).

Plot shape

The three most common plot shapes are: square, circular, and variable. Where equipment such as laser measuring devices are used, circular plots are considered quicker to establish than square or rectangular plots, and the area measurement is generally more accurate. However they can be difficult to establish where visibility is poor (such as in dense forests). Plots can also be measured as a stand-alone single plot, or as a 'nested' plot. In a nested plot design, consecutively larger plots are used to sample larger trees, while smaller size trees are only measured in smaller plots. This can be more efficient than single plots, where there is high variability in tree diameter, such as in multi-age natural forests. In other words, nested plots allow the field crew to measure smaller trees in a smaller plot size, in cases where there is a high density of small trees. Variable size plots are not fixed in size. Rather, the trees to be measured in the plot are determined by some parameter of interest (typically basal area, tree diameter, or less commonly height). For example, a factor gauge or prism wedge might be used to select trees to be measured on the basis of basal area. An in-depth discussion of variable sampling techniques is beyond the scope of this document, but more information can be obtained from the references cited at the back.

Step 4: Determine the frequency of measurement

A forest carbon sampling program might only be required to give a 'one-off' estimate of forest carbon stock. Alternatively, the forest manager may be interested in determining the change in forest carbon over time. In the latter case, the sampling process will need to be repeated at set intervals over time. Where repeated measurements are required, the frequency of measurement should be proportional to the rate of carbon stock change. For example, in a newly established plantation, the rate of carbon sequestration could be quite rapid, and therefore sampling every three years may be warranted. However if the inventory manager was sampling the soil carbon pool in a mature native forest in which no management changes have occurred, re-measurement may only need occur every 20 years.

Where sampling is also conducted for calculation of commercial timber volume, it is recommended that carbon sampling be conducted alongside the commercial timber inventory, as the measurements required are often the same.

When re-measurement does occur, care should be taken to conduct the measurements in the same season as previous inventories, so that any effect of seasonal variation is excluded.

Note that if the sampling program is being designed in accordance with a Carbon Farming Initiative (CFI) or Emissions Reduction Fund (ERF) methodology, the methodology rules will specify the range of reporting and crediting periods. This will determine the minimum and maximum frequency of sampling.

Assessment 4

For the same forest examined in Assessment 1, prepare a carbon sampling plan, outlining your recommended carbon sampling program for this forest. This plan should discuss the following aspects of the recommended sampling program, including justification for your choices:

1. Purpose and objectives
2. Scope
3. WH&S and environmental considerations
4. Sampling strategy, including recommended stratification system, if any
5. Carbon pools measured
6. Plot number, type and size, using the Winrock Sampling Calculator to make your decisions
7. Measurement frequency
8. Process for consulting with relevant stakeholders about the plan.

The plan should be accompanied by relevant maps, diagrams, and copies of any calculations. The plan should also be accompanied by a shapefile, showing the strata or project boundaries, generated using the Carbon Mapping Tool according to the procedure described for Assessment Task 1.2.

2. PREPARE FOR CARBON STOCK SAMPLING ACTIVITIES

LEARNING OBJECTIVES FOR THIS SECTION

At the completion of this Section, students should be able to:

- Prepare logistics for implementation of a forest carbon sampling program, including procedures for obtaining relevant approvals
- Assemble a team of people with all skills necessary for implementation of a forest carbon sampling program
- Identify plot locations using site maps and plans
- Identify potential hazards and risks, and implement appropriate control mechanisms

ORGANISE LOGISTICS

Effective planning to undertake a carbon sampling program includes well organised logistics, and this will help deliver cost effective results. Depending on the remoteness of the sample location, undertaking a forest carbon sampling program can have relatively small or very large logistical requirements. In relatively well populated locations, and/or within close proximity to a field office, the field inventory crew are unlikely to be camping out onsite. In this case, the main logistical preparations are related to sourcing of staff, equipment, approvals, and ensuring a safe workplace. If the sampling location is remote, the field inventory team may need to camp out onsite, in which case camping equipment and food will be required, as well as systems implemented for 'working remotely'.

In all cases, it is good practice to ensure the field team has a well-serviced vehicle appropriate to the terrain, and that someone back in the office is nominated as the point person, to be made aware of the field team's planned activities (including locations) each day. It is good practice to prepare Standard Operating Procedures (SOPs) for communication of field activities and travel plans, as described in more detail later in this document.

The following list gives an idea of the basic equipment and supplies that are typically required for carbon sampling field crews:

- GPS, for navigation to plot locations
- Diameter tape (i.e. a girth measuring tape with 'π' embedded within it), for measuring Diameter at Breast Height at 1.3m
- Laser rangefinder/ distance measuring device, for measuring tree height (if required). Otherwise, a clinometer and measuring tape can be used.
- Measuring tape, for laying out plots
- Corner posts/stakes
- Metal sampling frame (if litter is being measured)
- 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), pens/pencils
- Flagging tape
- Maps
- Camera

- Safety equipment such as a first aid kit, hard hat, sun protection, high visibility vest, etc[12]

If soil carbon is being measured, a range of other equipment will be required such as a bulk density sampler and field scales.

ASSEMBLE CARBON SAMPLING TEAM

Implementation of a carbon sampling program will typically require team members with the following responsibilities, noting that one individual may perform several functions listed below:

- Forest statistician/sampling specialist – responsible for designing the sampling program, processing and analysing the data when it comes in from the field, performing statistical calculations to determine if target precision has been met.
- GIS/mapping specialist – responsible for developing the forest stratification system, mapping of plot locations, and generation of locational maps as required
- Logistics officer – responsible for procurement of field equipment, arranging travel plans, organizing training if applicable, obtaining required permissions and approvals, and ensuring compliance with WH&S 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 SOPs, planning daily activities, reporting planned activities to the point person in the office at the beginning of each day, and overseeing the Quality Assurance/Quality Control (QA/QC) procedures
- Field measurement crew – responsible for taking field measurements in accordance with the SOPs and under the instruction of the field team leader, entering data onto the standardized templates, and sending data to the forest statistician/sampling specialist

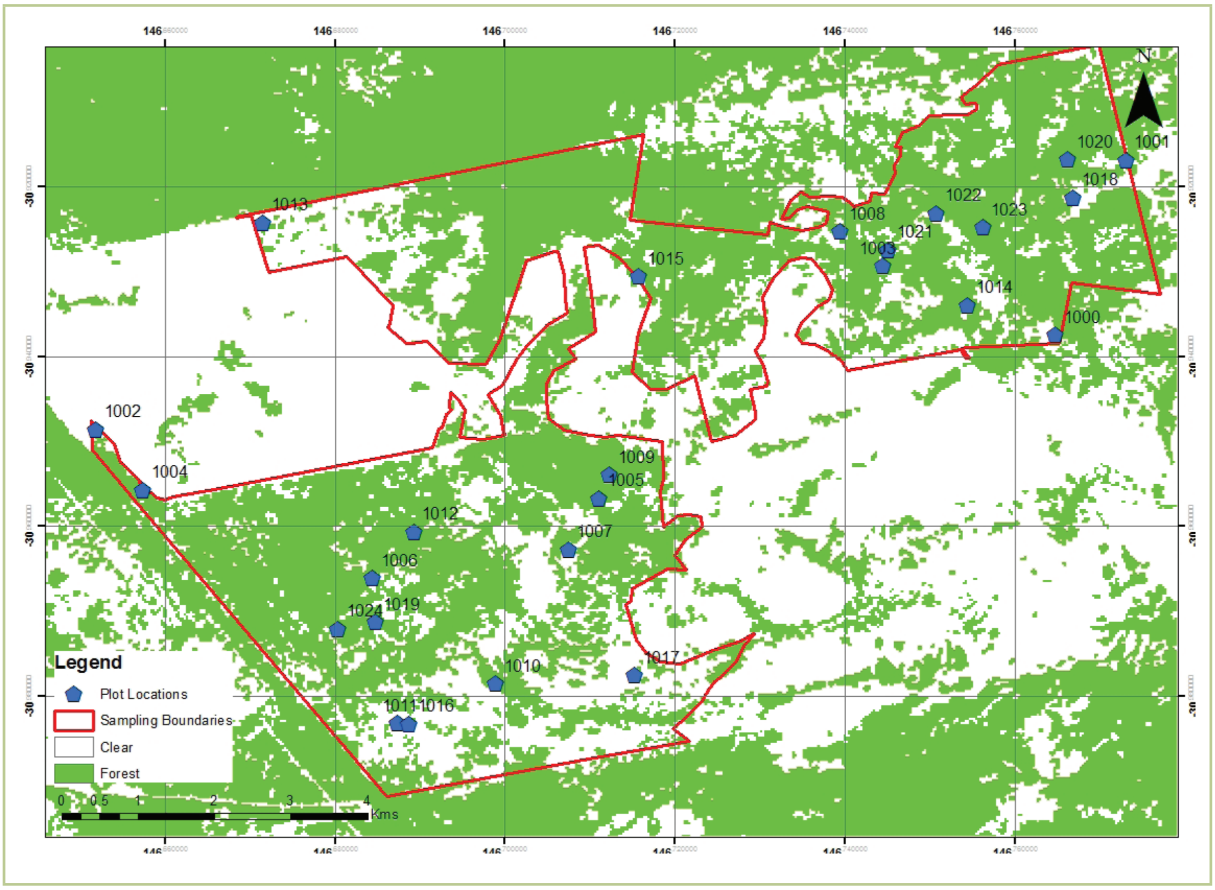
In some cases, an external contractor may be engaged to undertake the field sampling, rather than recruitment of these positions in-house. In this case, this checklist above should be used to ensure the contractor is adequately resourced for the task.

IDENTIFY PLOT LOCATIONS USING SITE MAPS AND PLANS

The location of plots should be determined prior to entering the field. Plot locations should be determined in compliance with the chosen sampling method (for example, stratified systematic sampling). Location of plots is typically done using GIS software, which has a series of functions that can be used to objectively determine plot locations. The GIS can also be used to define exclusion areas or buffer zones.

12 For additional information about first aid requirements, it is recommended to read the Code of Practice for First Aid in the Workplace. Available at: http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/693/First%20aid%20in%20the%20workplace.pdf

Figure 4 Example of a map showing plot locations



Once mapped in the GIS, the plot coordinates are then uploaded onto a handheld GPS. If required, approval to visit the sample site locations should be obtained well in advance of the inventory. The logistics officer and field team leader should identify and ensure that all administrative procedures and approvals are completed before entering the field.

IDENTIFY POTENTIAL RISKS & HAZARDS

The potential risks and hazards associated with implementation of the field sampling program must be identified prior to entering the field, and appropriate control mechanisms implemented and communicated to all staff. Table 3 below summarises some of the key risks that might be encountered when implementing a carbon sampling program, and proposes possible control mechanisms.

Table 3 Potential risks and hazards frequently encountered during field sampling, and possible control mechanisms

Hazard/risk	Possible control mechanism
Physical injury occurring during field work	• All field crews must carry a first aid kit and two way radio, satellite phone or mobile phone. Batteries for electronic field equipment must be checked before entering the field each day • Field crews must have a minimum of 3 persons (one to stay with an injured person, one to seek help if required) • Field crews should wear hard hats and other appropriate Personal Protective Equipment (PPE) if the average tree height is greater than 2m • Daily activities and travel plans must be logged with a point person back in the office at the beginning of each day • All team members should have knowledge of the nearest medical facility at any point in time • Before exiting the vehicle to conduct field work, the field crew should leave a note on the dashboard indicating the time, and the latitude and longitude of plot coordinates • Identify and map helicopter pads that could be required in an emergency, and communicate these to the point person and local emergency services personnel
Heat exhaustion, dehydration, sunburn, snake bite	• Field crews should carry a first aid kit, sunscreen and adequate water at all times • Field crew should wear appropriate clothing with long sleeves, sturdy boots, long pants and wide brimmed hat
Vehicle accident	• The designated driver should be properly trained and licensed in driving of the vehicle, including four wheel driving training if applicable • The field vehicle should have a detailed map of all roads, waterways and hazards in the sampling area • The vehicle should be appropriate to the terrain
Crew getting lost	• All field crews must carry a GPS, and two way radio, satellite phone or mobile phone. Batteries must be checked before entering the field each day • Field crews should carry an EPRIB locator beacon in remote areas with no or patchy mobile phone range
Trip/fall hazard on steep or unstable terrain	• The GIS/Mapping Specialist should provide the field team leader with a topographical map, clearing marking all steep or unstable areas • Wherever possible, the field team leader should discuss potential hazards with someone familiar with the local area • If the field work is to take place in former mine sites, the location of all former mines should be mapped, if possible
Fire	• Crews must not work during a total fire ban day • If smoke is detected during field work, the field crew should immediately return to the vehicle and contact the point person in the office to determine the nature of the fire hazard
Electrocution	• If digging is required (for example to excavate soil for bulk density sampling), the field team leader must obtain a 'dial before you dig' report on the location of potential unground wires and cables, prior to entering the field.

Assessment 5

1. For the carbon sampling plan prepared in Assessment 4, include additional sections covering the following topics, again explaining the rationale for your choices:

   Risk and hazard analysis

   Logistics plan

   Description of the carbon sampling team

   Map of plot locations

3. CONDUCT CARBON STOCK SAMPLING COLLECTION

LEARNING OBJECTIVES FOR THIS SECTION

At the completion of this Section, students should be able to:

- Coordinate sampling activities onsite prior to commencement of and during the work activity
- Describe procedures to inspect and test sampling equipment
- Oversee field sampling procedures in accordance with SOPs and the sampling plan

Note that it is considered beyond the scope of this document to provide specific instructions related to field-based measurement procedures. Rather this document focuses on aspects of the carbon stock sampling program related exclusively to carbon sampling. It is assumed that field measurement procedures are covered as part of the pre-requisite subject, *FPIFGM6203 – Manage sustainable tree inventory*. More information also can be obtained from the reference material cited at the end of this document.

COORDINATE SAMPLING ACTIVITIES

Once the sampling team has been engaged, the logistics officer should ensure that all staff receive an organisational induction and other training as required. This will cover work place health and safety, emergency response procedures, protective clothing and equipment, environmental management and other requirements. In addition, members of the sampling team should receive training on specific sampling plan requirements as necessary, including:

- Project objectives, strategies and methods
- Reporting mechanisms for monitoring time and resources
- Sampling techniques, including use and maintenance of tools and equipment
- Recording of sampling results

Once in the field, it will be the responsibility of the field team leader to ensure that work health and safety practices are followed and that sampling objectives are met.

INSPECT AND TEST SAMPLING EQUIPMENT

All electronic devices such as GPS, two-way radio or telephone, etc., will need to be tested for functionality at the beginning of each day prior to entering the field. Such devices should be used and calibrated (where required) in accordance with the manufacturer's instructions.

CONDUCT SAMPLING IN ACCORDANCE WITH PLAN

The field team leader should prepare SOPs to cover all aspects of field measurements. The logistics officer and field team leader should ensure that all field crew are properly trained in the implementation of these SOPs before entering the field. The SOPs should be prepared in line with best practice procedures, for example using some of the resources listed in the references section of this document. For a typical forest carbon sampling program, SOPs are likely to cover the following measurement activities:

- Navigation to plot locations using a GPS
- Establishment and marking of plot boundaries, including procedures to deal with slope
- Procedures for relocation of plots, where required due to safety concerns (noting that plots should not be relocated for any other reason)
- Measurement of diameter at breast height
- Measurement of tree height
- Identification of tree species and/or strata
- Dealing with boundary trees, and plots located on the edge of project boundaries
- Data recording and transcription procedures

In addition to the SOPs, a Sampling Plan should also be prepared. Components of a sampling plan might include:

- Sampling objectives
- Sampling method, plot type and number
- Summary of attributes to be measured
- Work health and safety requirements
- Emergency response procedures
- Summary of legal responsibilities and permissions
- Field crew positions and responsibilities
- List of field equipment
- Logistics related to travel, fuel and food
- Work plan
- Costing and budget
- Procedures for review and continuous improvement

Once drafted, all members of the sampling team should have the opportunity to provide comment on the Sampling Plan before it is signed off by senior management. The plan should be reviewed prior to each new sampling program, to ensure that any lessons learned are integrated into future training programs.

Activity 3.1

1. Access the owner manual for the Garmin GPSMap 62 Series handheld GPS (Available at: http://static.garmincdn.com/pumac/GPSMAP62_OM_EN.pdf).[13] Search the pdf for the term 'calibrate'. Prepare an SOP for use of this GPS for navigation to a plot location, including any required GPS calibration procedures.

13 Accessed 31 May 2014

Assessment 6

1. Using some of the resources listed in the Bibliography of this document, prepare an SOP for the field measurement procedures that are required for the carbon sampling plan you developed in Assessment Task 1.4. This SOP should cover, at a minimum, the following procedures:
    - Establishment and marking of plot boundaries, including procedures to deal with slope
    - Procedures for relocation of plots
    - Identification of tree species and/or strata
    - Measurement of diameter at breast height
    - Measurement of tree height
    - Dealing with boundary trees, and plots located on the edge of project boundaries
    - Data recording and transcription procedures

4. INTERPRET RESULTS

LEARNING OBJECTIVES FOR THIS SECTION

At the completion of this Section, students should be able to:

- Estimate forest carbon stocks from the data collected, including estimation of carbon stock in the aboveground biomass, litter, dead wood and soils pools
- Implement a quality assurance and quality control program
- Review the implementation of the sampling program, and provide recommendations for continuous improvement

ESTIMATE CARBON STOCK OF THE ABOVEGROUND BIOMASS (TREES)

Having collected the forest carbon stock data, the results must be analysed in order to produce statistically defensible estimates of forest carbon stock. Typically, there are three main steps involved in estimating forest carbon stock from field data. These are described below.

Step 1: Calculate aboveground biomass of each tree

Calculation of tree biomass is the first step in estimating the carbon stock of the aboveground biomass. 'Aboveground Biomass' is the collective term used to describe all of the plant tissues that make up the tree above the soil surface. It includes the trunk, branches, leaves and twigs. Almost all tree biomass is universally half carbon by dry weight (i.e. the weight when all the water is removed), so if the weight of aboveground biomass is known, it can be readily converted to carbon stock estimates.

Aboveground biomass per tree is calculated by inputting field data into a 'regression equation'. A spreadsheet is normally used to undertake this calculation. The regression equation will relate readily measurable components of the forest (for example, diameter at breast height), to the variable of interest (for example, total aboveground biomass). Two types of regression equations can be used to estimate carbon 1) an allometric equation, which is an equation that that estimates tree biomass, or dry weight of the tree; or 2) a commercial volume equation for estimation of tree volume (usually for the stem only). When designing a forest carbon sampling program from the outset, it is preferable to use an allometric biomass equation, rather than a commercial volume equation. This is because an allometric equation provides a more 'direct' estimate of aboveground biomass. However, the advantage of using a commercial volume equation is that it allows the inventory manager to convert existing timber inventory data to carbon stock estimates, through the application of a 'Biomass Conversion and Expansion Factor' (BCEF). The BCEF converts volume of the tree bole (normally expressed in cubic metres), to total tree biomass (normally expressed in kilograms of dry matter). It also accounts for biomass stored in the 'non-commercial' components of the tree such as branches, leaves and twigs. It is important to note that BCEFs are unreliable when applied to forests where the structure differs from the forest in which the BCEF was developed. If designing a carbon sampling program in accordance with a specific standard or carbon market, the methodology may specify whether or not commercial volume equations are permitted for estimation of aboveground biomass.

It is good practice to use allometric or volume equations that have been published in peer-reviewed literature. The equation should also be appropriate for the species, growth form, tree size, and general ecology of the forest being sampled (sometimes referred to as the 'allometric domain' of the equation. For example, it is not appropriate to use an allometric equation for blue gum *(Eucalyptus globulus)* for blue mallee (*Eucalyptus polybractea).* Some regression equations are species specific, while others have been developed for a group of species (such as Eucalypt woodlands).

Activity 4.1

Use the following allometric equation (which is applicable for high rainfall eucalypt species), to estimate the biomass of a plot containing trees with the following measured DBH in cm: 10.1; 48.7; 22.8; 39.5; 14.2; 18.7; 72.1; 21.6; 5.8; 49.7.

AGB = exp [-2.21 + 2.40*(Ln DBH)] * 1.1

Where:
AGB = Aboveground Biomass (kg dry matter per tree)
DBH = Diameter at Breast Height (cm)

Tip: Type the following equation into Excel to calculate AGB using this allometric equation
'=EXP(-2.21+2.4*(LN(Cell containing DBH)))*1.1'

Plot the results in Excel using a scatter diagram. What do you notice about the results? Which trees contribute most to aboveground biomass stock?

Step 2: Convert biomass per tree to carbon stock per hectare

Step 2a: Convert the biomass values from kilograms per tree, to tonnes per tree. This involves dividing the biomass values for each tree by 1000.

Step 2b: Sum the biomass of all trees in the plot, to give a single figure representing the total aboveground biomass of the plot, expressed in tonnes.

Step 2c: Extrapolate plot biomass values to a per hectare figure. To do this, the size of the plot must be determined relative to one hectare. This will then give a plot 'Expansion Factor', which is used to convert plot data to a per hectare basis.

To calculate the plot Expansion Factor (XF), apply the following equation:

$$XF = \frac{10{,}000 \text{ m}^2}{\text{Plot dimensions (m}^2\text{)}}$$

For example, a plot with dimensions of 50m x 20m, would have a plot XF of:

$$XF = \frac{10{,}000 \text{ m}^2}{50 * 20 \text{ m}^2} = 10$$

Step 2d: Convert biomass per hectare to carbon stock per hectare. As mentioned previously, plant tissue is almost always universally half carbon by dry weight. So we can multiply our per hectare Total Aboveground Biomass figure by 0.50, to give the plot carbon stock, in tonnes of carbon per hectare.

Step 2e. Calculate carbon stock for the entire stratum. Calculate the average carbon stock per hectare for all plots in the stratum. This can be achieved via manual calculations (i.e. summing all carbon stock values, then dividing by the number of plots). Alternatively it can be achieved using the 'AVERAGE' function in Excel. The result is then multiplied by the total area of the stratum, to derive a total carbon stock figure for the entire stratum. I.e.:

Total carbon stock for a stratum (t C) = Area of stratum (ha) * Average C stock of stratum (t C ha^{-1})

If there is only one stratum, then this calculation will only be performed once.

Step 2f: Calculate carbon stock for the entire forest. To calculate total carbon stock of the forest, the carbon stock for each of all strata are summed. I.e.:

Total forest carbon stock (t C) = Sum of totals of carbon stock for each stratum (t C)

Assessment 7

1. A forest owner establishes a plot in a high rainfall eucalypt forest. The forest owner measures trees with the following diameters (cm): 63.4; 25.8; 17.2; 36.5; 27.8; 93.6; 12.5; 16.4; 43.7; 10.3; 13.7. The forest owner uses the allometric equation described in Activity 4.1 to calculate the total carbon stock for this plot (expressed on a per hectare basis) in Excel. Input this data into an Excel spreadsheet, and calculate the aboveground biomass for each tree, first expressed in kg of dry matter per tree, and then expressed in tonnes. The formulae to be used in Excel are provided to assist. Then calculate the total aboveground biomass for the plot.

Figure 5 Example calculation of total carbon stock for a high rainfall eucalypt forest

	Column					
	A	B	C	D	E	F
Parameter	DBH	AGB	AGB	AGB	AGB	Total carbon stock
Unit	cm	kg tree-1	t tree – 1	t plot -1	t ha -1	t C ha -1
Excel equation	N/A	= EXP(2.21+2.4*(LN(DBH)))*1.1	=rowC/1000	=sum (columnD)	=E1*8(Plot XF)	=F1*0.50
1	6.34	2,550.45	2.55	11.78	94.21	44.10
2	25.8	294.77	0.29			
3	17.2	111.40	0.11			
4	36.5	677.80	0.68			
5	27.8	342.62	0.35			
6	93.6	6,496.27	6.50			
7	12.5	51.78	0.05			
8	16.4	99.36	0.10			
9	43.7	1,044.14	1.04			
10	10.3	32.54	0.03			
11	13.7	64.53	0.06			

2. The plot dimensions are 50 x 25m, resulting in a plot expansion factor (XF) of 8. Show in Excel how this XF was calculated.

3. What is the total carbon stock per hectare for this plot?

Step 3: Convert carbon stock to CO_2e equivalents

Most scientists like to report forest carbon stock as tonnes per hectare (i.e. t C ha^{-1}), as this is the form of carbon that is biologically stored in the plant tissue. However most carbon markets traders prefer forest carbon to be reported as tonnes of CO_2 equivalent (often abbreviated to 'CO_2e'). Therefore, the results of some forest carbon sampling programs may need to be expressed in this form. If so, this involves multiplying the total forest carbon stock (t C), by the molecular ratio of CO_2 relative to carbon, which is $^{44}/_{12}$ (or, 3.667), as expressed in the following equation:

Total forest carbon stock (t CO_2e) = Total forest carbon stock (t C) * ($^{44}/_{12}$).

Step 4: Calculate carbon stock change, if required

If a previous carbon assessment has taken place, the forest manager is likely to be interested in the total change in carbon stocks over time. In addition, reporting of the carbon stock change (as opposed to carbon stock at a single point in time) is often required for compliance against carbon market standards. In this case, the carbon stock change is simply the carbon stock at time two (e.g., 2014), deducted from the carbon stock at time one (e.g. 2005). I.e.:

Change in forest carbon stock (t C or t CO_2e) = (Carbon stock at time 2) – (Carbon stock at time 1)

Step 5: Calculate uncertainty

In the context of forest carbon sampling, 'uncertainty' is defined as the level of error associated with a carbon stock estimate. There are many sources of error associated with carbon stock estimates, including measurement error (i.e. as a result of errors in field sampling techniques or equipment), modelling errors (i.e. due to errors in application of a carbon yield forecasts or regression equations), and sampling errors (i.e. as a result of taking measurements from a sub-sample of the population).

Throughout the design and implementation of a carbon sampling program, processes should be implemented to minimise measurement errors, for example through routine calibration of field equipment. It is also good practice to report the level of sampling error associated with a carbon stock estimate. This is normally expressed by reporting the sampling error as a percentage of the mean, in relation to a specified confidence limit (typically 90 – 95%). The sampling error can normally be expressed as the 'standard error', as described in the following equation:

$$SE_{sample,i} = \frac{S_i}{\sqrt{n_i}}$$

Where:

$SE_{sample,i}$ = Standard error of the biomass sample for strata i
$S_{i,r}$ = standard deviation of the biomass sample data in strata i
n = number of samples in strata i

A more detailed description of uncertainty analysis is beyond the scope of this document, however students can find out more from accessing the resources in the Bibliography.

Activity 4.2

1. Calculate the standard deviation of the biomass survey described in Assessment 7.
   Tip: Use the following formula in Excel '=STDEV.S(Cell References of AGB Data)'.

Assessment 8

1. Access the CFI 'Guidelines for the development of field-based reforestation methodologies', available at: http://www.climatechange.gov.au/sites/climatechange/files/documents/03_2013/sampling-guidelines-20121128.pdf.
2. Review the document and create a checklist of items that should be included within CFI methodologies that use single tree allometric equations.
3. Based on your checklist, include any additional recommendations or specifications within your SOPs, as prepared in Assessment 6.

ESTIMATE CARBON STOCK OF THE BELOWGROUND BIOMASS (TREE ROOTS)

The carbon stock of the belowground biomass can be estimated in one of three ways: 1) by application of a root:shoot ratio; 2) by 'destructive' sampling (i.e. where the tree roots are excavated in the field and weighed); and 3) by application of a regression equation (i.e. where the root biomass is estimated based on measurement of some other variable, normally aboveground biomass.

In practice, most carbon sampling programs apply the first method, i.e. a root:shoot ratio. This ratio is based on the assumption that for a specified species or forest type, the belowground biomass is normally well-correlated with the quantity of aboveground biomass. Therefore, if the aboveground biomass is known, then the quantity of belowground biomass can be estimated by applying the following equation:

Belowground biomass (t dm ha^{-1}) = Aboveground biomass x Root:Shoot Ratio.

The carbon stock of the belowground biomass is then calculated by application of Steps 2 – 4, as described earlier for aboveground biomass.

ESTIMATE CARBON STOCK OF THE DEAD WOOD POOL

There are multiple methods of estimating the carbon stock of the dead wood. However the most commonly used method is known as the 'line intersect' method. This involves laying out measuring tapes along the forest floor, and recording the diameter and density class of each piece of dead wood intersecting the measuring tape. Carbon stock can then be estimated according to three steps:

Step 1: Collect sub-samples of wood for each density class

According to the line intersect method, dead wood must be classified according to one of three density classes, either sound, intermediate or rotten. When in the field, a number of wood blocks (approx. 5 – 10) of each density class should be collected, and taken to a laboratory to determine the average wood density of each class according to the following equation:

Wood density (g m^{-3}) = Oven dry mass of sample (g) / Volume of sample (m^3)

Step 2: Calculate the volume of dead wood for each density class in each plot

For each wood density class (sound, intermediate, rotten), the volume of dead wood in each plot can be calculated by applying the following equation:

$$\text{Volume } (m^3\ ha^{-1}) = \pi^2 \times [(d_1^2 + d_2^2 + d_3^2 + \ldots d_n^2)/8L]$$

Where:
$d_1^2 \ldots d_n^2$ = diameter of each piece of dead wood intersecting the measuring tape (cm)
L = Total length of the measuring tape (m)

Step 3: Calculate the biomass of dead wood for each density class in each plot

The biomass of dead wood in each class can be calculated according to the following equation:

Biomass of dead wood (t ha^{-1}) = Volume of dead wood (m^3 ha^{-1}) x Density of dead wood class (g m^{-3})

Carbon and CO_2e stock of dead wood can then be calculated by application of Steps 2 – 4 that were applied earlier to aboveground biomass.

ESTIMATE CARBON STOCK OF THE LITTER POOL

Carbon stock of the litter layer is normally measured by collecting all litter within a sampling frame with a known area (normally around 1m x 1m). The 'wet weight' of all litter collected from the sampling frame is then measured in the field using a set of field scales. A sub-sample is then collected and weighed, and this is taken back to the laboratory to determine its dry weight. The total mass of the litter sample is then calculated according to two steps:

Step 1: Calculate the dry weight of all litter within sample frame

The dry weight of all litter within the sampling frame is calculated by application of a dry weight:wet weight ratio, as calculated using the litter sub-sample. This ratio is then applied to the wet weight of the litter sample, by applying the following equation:

Dry weight of litter sample = (Subsample dry weight/Subsample wet weight) x Wet weight litter frame sample

Step 2: Calculate the litter biomass on a per hectare basis

Total biomass of litter is estimated on a per hectare basis by application of a plot expansion factor, which is as described in Step 2c for aboveground biomass. i.e.:

Litter biomass (t dm ha^{-1}) = Dry weight of litter calculated in Step 1 x Plot Expansion Factor

Carbon and CO_2e stock are then calculated via application of Steps 2 – 4 as described for aboveground biomass.

ESTIMATE CARBON STOCK OF THE SOIL

Estimation of soil carbon stock involves measurement of three variables: 1) soil depth; 2) bulk density (i.e. mass of soil per unit of volume); and 3) carbon content of the sample, as determined using specialised laboratory equipment. A more detailed description of these procedures and terms can be accessed from the source material in the Bibliography. The carbon stock of soil can then be calculated by application of the following equation:

Soil organic carbon stock (t C ha^{-1}) = [Soil bulk density (g m^{-3}) x Soil depth (cm) x Carbon Content (%)] x 100

Assessment 9

1. Access the CFI Methodology, titled 'Carbon Farming (Quantifying Carbon Sequestration by Permanent Environmental Plantings of Native Species using the CFI Reforestation Modelling Tool) Methodology Determination 2012', available at: http://www.comlaw.gov.au/Details/F2012L01340. Create a template for a carbon accounting spreadsheet in Excel, covering all of the calculations specified in this methodology. The spreadsheet should refer to the relevant section and equation numbers as shown in the methodology.

IMPLEMENT A QUALITY ASSURANCE AND QUALITY CONTROL PROGRAM

It is good practice for a carbon sampling program to be accompanied by a Quality Assurance and Quality Control (QA/QC) plan. A QA/QC plan describes the procedures, checks, audits, and corrective actions to ensure that sampling is conducted according to the highest achievable quality. The QA/QC plan 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. The QA/QC plan should cover the following aspects of the sampling program, as described below: 1) mapping and GIS; 2) field measurements; 3) laboratory procedures, if required; 4) data entry and analysis; and 5) data filing and storage.

Mapping and GIS

The Mapping/GIS Specialist should be formally trained in geospatial analysis. A dedicated QA/QC plan and SOPs for mapping and GIS should be prepared, covering the following issues:

- Processing of imagery
- Spatial projections
- Obtaining and processing data
- Data completeness and consistency

- Designing a QC workflow
- Procedure for recording and tracking of errors
- Naming and storage of spatial files

Field measurements

The field measurement crew should be well-trained in all aspects of the field inventory, and must conduct field measurements (including required calibration) in accordance with the SOPs. The field team leader should supervise the field crew at all times to ensure correct implementation of field SOPs. 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 (say 5 – 10%) are re-measured by an independent field crew.

Laboratory procedures

Calibration of laboratory instruments should be routinely carried out according to the manufacturers' instructions and the organisation's SOPs. If an external contractor is used for laboratory work, the logistics officer should check to ensure that:

- The contactor is certified to the relevant industry standard (i.e.. the National Association of Testing Authorities, NATA)
- All laboratory equipment is commercially certified, and
- Records of all calibration procedures are provided.

Data entry

It is good practice to prepare SOPs 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 hand-writing 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 biological range (for example, by not allowing entry of tree height values in excess of say 100 m).

Data filing and storage

It is good practice to prepare SOPs 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.

REVIEW IMPLEMENTATION OF THE SAMPLING PROGRAM, AND PROVIDE RECOMMENDATIONS FOR CONTINUOUS IMPROVEMENT

It is good practice to monitor the implementation of the sampling program. Areas for improvement can then be identified and reported to senior management. The following questions could be used as a guide for review of the sampling program:

- Were the objectives of the sampling program achieved? If not, what additional activities are required to achieve these objectives?
- Was the sampling program completed on time and within budget, and, if not, why not?
- Was the sampling method appropriate for the circumstances?

- What issues arose during the sampling program that still need to be resolved?
- What further training and development is desirable for project staff?
- Are there any other actions required and areas for improvement?

The review process should solicit feedback from all members of the sampling team. The results and recommendations of the review should be summarised in a written report, and reported to senior management.

5. USE GROWTH MODELS TO PREDICT BIOMASS AND CARBON STOCKS

In many cases, the forest manager will be interested to obtain a forecast of forest biomass and carbon stocks over time. This may be required for internal reporting purposes (i.e. to determine the carbon impact of certain management activities), or it may be required to estimate how much carbon might be available for sale in future. In this case, a 'growth model' will be used to develop an estimate of forest carbon stock change over time. This can either be an adaptation of an existing timber growth and yield model, or it might be a dedicated model for forecasting carbon stock.

LEARNING OBJECTIVES FOR THIS SECTION

At the completion of this Section, students should be able to:

- Select and appropriate forest growth model to forecast carbon stock changes over time; and
- Validate the model with field data

SELECT APPROPRIATE GROWTH MODEL

The Australian Government has developed the Full Carbon Accounting Model (FullCAM) model for forecasting carbon stock changes in forests. It has also developed the Reforestation Modelling Tool (RMT) as a user-friendly interface of the FullCAM model, with embedded defaults specifically for reforestation projects. Both FullCAM and RMT are available for download free of charge by following the links provided in the Bibliography of this document.

The RMT model allows users to estimate emissions and removals from reforestation projects, based on a limited set of user inputs (i.e. latitude and longitude of the project area, and size of the area to be modelled, and approximate planting density). At the time of writing, the model is only calibrated for mixed species environmental plantings.

The FullCAM model is far more detailed than the RMT, and is capable of modelling carbon stock changes in forest and agricultural systems. It also models emissions from land use changes, and a number of planned events such as fire management or thinning. However it can also produce results with a limited number of input parameters (i.e. same as those for RMT), providing that the user accepts all default parameters.

Alternatively, users may wish to choose other models. Factors to consider when choosing a carbon growth and yield model are:

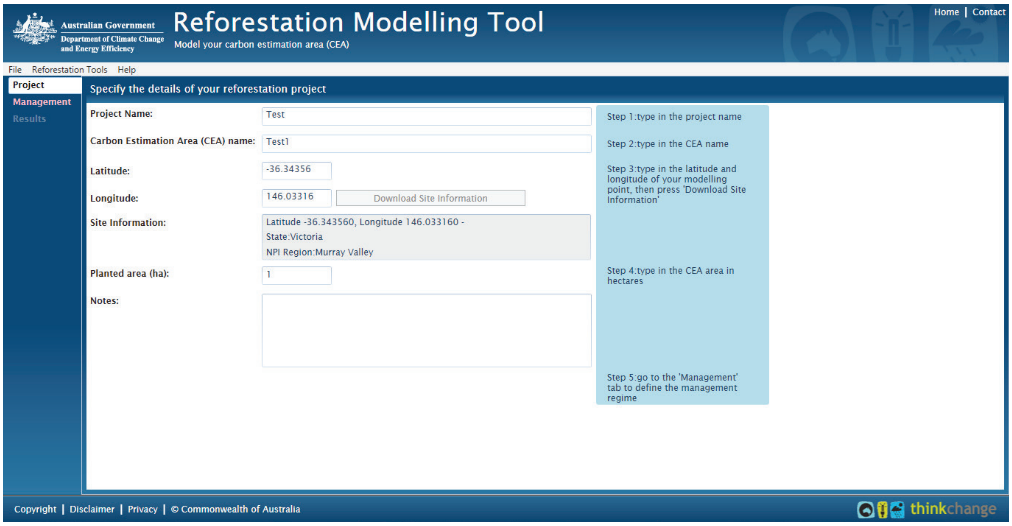
- Accuracy – are the results of the model scientifically defendable, for example with publications in peer-reviewed literature? How do the modelled results compare with actual measurements in the field?
- Ease of use – can existing staff use the model appropriately, or will external support be required to run the model?
- Relevance – does it include the tree species and management configurations needed? Does it include the carbon pools required?
- Data inputs – what data are required to run the model? Do data already exist, or will new data need to be collected? If new data are needed, how costly will be the collection?
- Model cost and availability – how expensive is the model? Are there commercial restrictions on its use?
- Documentation and support – is there a well-written user manual? Is there user support?

Activity 5.1

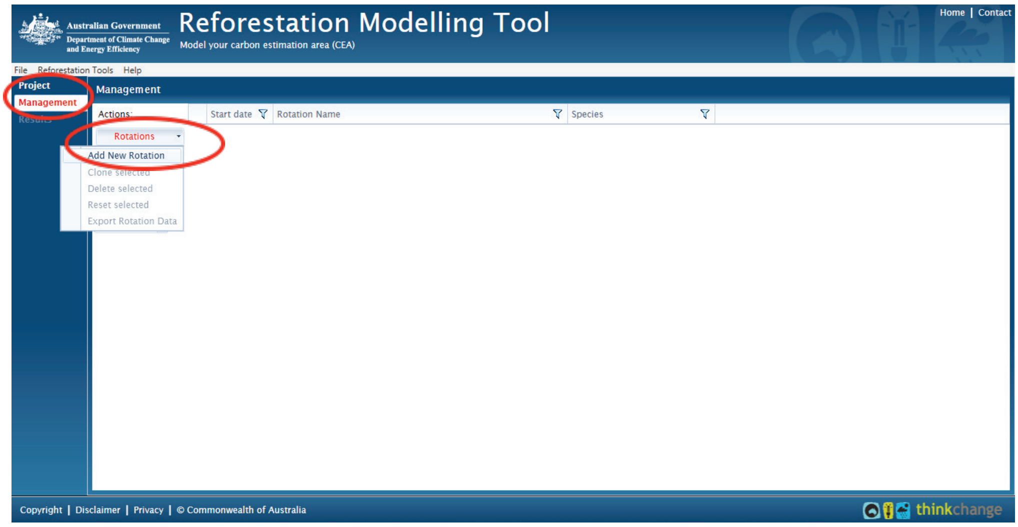
In this activity, the RMT model will be used to generate a carbon forecast for a newly planted forest at a nominated latitude and longitude.

Download a copy of the RMT model from the Reforestation Tools website:
http://ncat.climatechange.gov.au/cfirefor/RMT/Default.aspx

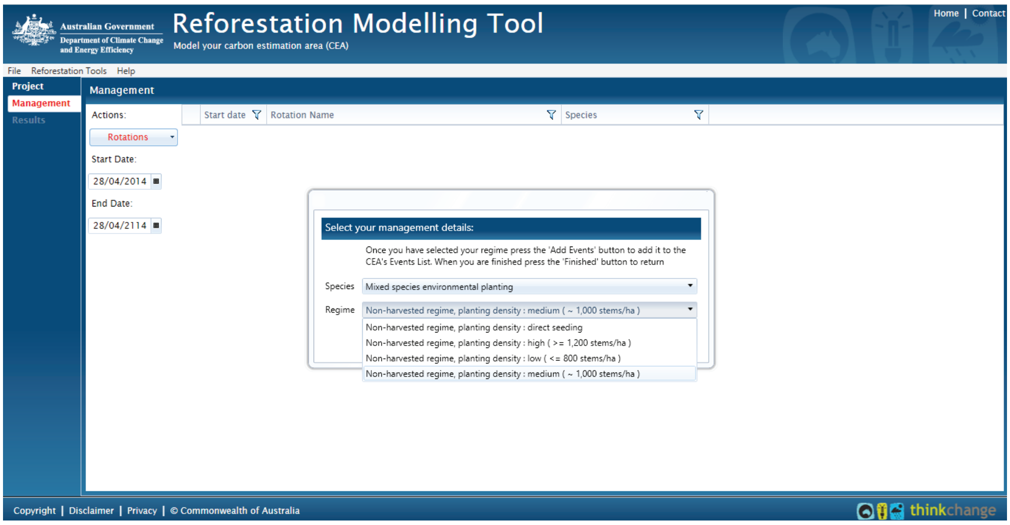
1. Choose a location where the forest will be planted. This could be anywhere in Australia. Enter a suitable project and CEA name into the RMT model, followed by the latitude and longitude (in decimal degrees) of the model point location for the forest (hint: the CMT or Google Earth can be useful for this purpose).
2. Click on 'download site information' button (the computer must have access to the internet at the time). This will access the Department's database, and download a range of site productivity information specific to the site (e.g. rainfall, temperature, soil type etc).



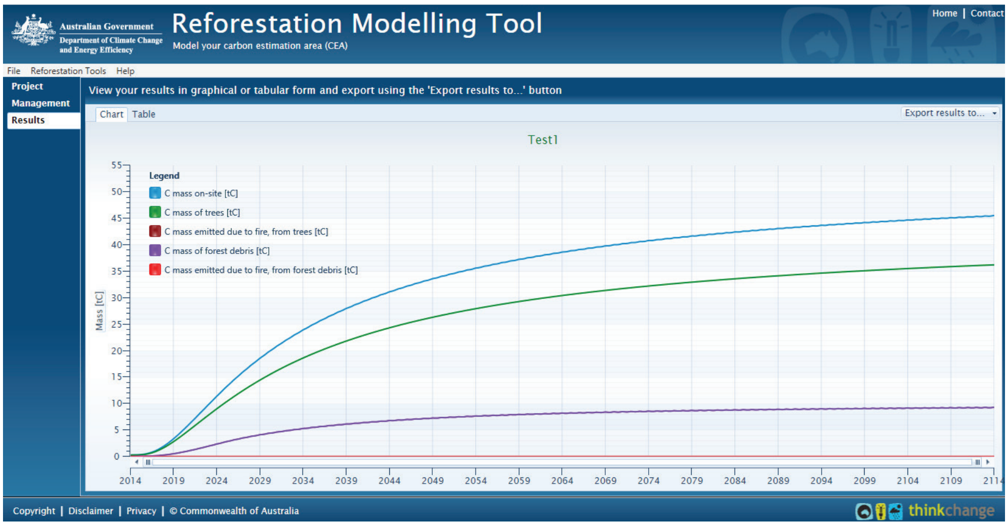
3. Enter in the area of planted forest (in hectares) to be modelled. Note that if the output is preferred in per hectare values, enter '1' into this box.
4. Click on the 'Management' tab to the left hand side of the screen. This will activate a new screen containing a dropdown box titled 'Rotations'. Click on this box, and select 'Add New Rotation'



5. Select 'Mixed species environmental planting' from the Species dropdown list. For the regime, select 'Non-harvested regime, planting density:medium (1000 stems/ha). Click 'Add Events' then 'Finished'.



6. Choose a start date and end date for the model simulation. The default is a 100 year simulation. Click on the 'Results' tab on the left hand side of the screen. This will run the model, and produce a graph showing the total carbon mass onsite, the carbon mass of trees, carbon mass due to fire (for both trees and forest debris), and the carbon mass of forest debris. Note that results are reported in t C, so if the output desired is t CO_2e, then the results will need to be converted to CO_2 in a separate spreadsheet.



7. Click on Export Results. This allows you to export your results in a format suitable for further analysis, such as an Excel spreadsheet. Export your results as an Excel spreadsheet, and practice converting the results to CO_2e.

8. Take some time to explore the features of the model, save and close the model.

Assessment 10

1. Using the carbon accounting template prepared in Assessment 9, calculate the 'net abatement' for the forest modelled in Activity 4.1, in accordance 'Carbon Farming (Quantifying Carbon Sequestration by Permanent Environmental Plantings of Native Species using the CFI Reforestation Modelling Tool) Methodology Determination 2012'.

VALIDATE THE MODEL WITH FIELD DATA

A well-calibrated model provides an excellent mechanism to forecast carbon stocks in between field measurements. However if a reasonable level of assurance regarding model accuracy is required (as is the case for selling carbon in most carbon markets), then the selected model will need to be 'validated' with field data. This involves comparison of carbon stock values predicted by the model, to actual measurements collected in the field. Statistics are then applied to determine whether the results are statistically different. If they are, the model is not considered to adequately represent the forest being sampled, and further work may be required to tailor the model to your specific forest. A forest statistician can be engaged for this purpose.

SOURCES AND FURTHER READING

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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			
Technical skills to select sampling techniques and create sampling designs; identify species growing in the target area; and identify components of the forest/plantation that contain carbon stocks			
Communication skills to use appropriate consultative, communication and interpersonal techniques with colleagues and others; and present written and oral information to a wide range of individuals and groups			
Literacy skills to analyse qualitative and quantitative information and data; prepare site maps and plans; and accurately prepare a range of reports, documentation and submissions where precise meaning is required			
Numeracy skills to use growth models to predict growth; and use and adapt complex maps and diagrams			
Problem-solving skills to demonstrate time and project management			
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 undertaking carbon stock sampling of forests and plantations			

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, site and management standards, requirements, policies and processes for undertaking carbon stock sampling of forests and plantations			
Environmental risks and hazards associated with undertaking carbon stock sampling of forests and plantations			
Using energy effectively and efficiently			
Using materials effectively and efficiently			
Procedures for the development and implementation of a range of environmental management strategies			
Data collection and analysis methods			
Map and plan preparation techniques			
Characteristics and growth habits of local vegetation			
Soil characteristics and topography of local area			
Use and application of appropriate survey and assessment equipment			
Statistical analysis techniques applicable to biomass and carbon assessments			
Sampling techniques applicable to biomass and carbon assessments			
Use and application of growth models			
Established communication channels and protocols			
Problem identification and resolution strategies			
Types of tools and equipment, and procedures for their safe use and maintenance			
Appropriate mathematical procedures for estimation and measurement			
Procedures for the recording, reporting and maintenance of workplace records and 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 an errors and suggested improvements.

Resource title	***Undertake Carbon Stock Sampling of Forests and Plantations***

Page	**What is in error**	**Suggested improvement**

Is there a link to your suggested improvement?

Additional comments

Click here to email your feedback form to ForestWorks

ACKNOWLEDGEMENTS

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.

Project team

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

Technical review

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Steering committee

Thank you to the steering committee for project oversight to ensure the resources met the needs of possible end user groups including enterprises, RTOs, and Higher Education. The committee was made up of representatives from TAFE NSW, Macquarie Agriculture, Killin Management, Green Triangle Forest Products, Forestry Tasmania, Southern Cross University, Timber Training Creswick, HVP, McLeod Industry Training and Forestworks ISC.

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