Technical Reference Guide for the Carbon Credits (Carbon Farming Initiative) (Measurement Based Methods for New Farm Forestry Plantations) Methodology Determination 2014

Version 1.0

Introduction

This Technical Reference Guide for the Measurement Based Methods for New Farm Forestry Plantations Version 1.0, published 8 August 2014, provides project proponents details on the various methods that must be applied in order to successfully implement a Carbon Farming Initiative (CFI) project under the *Carbon Credits (Carbon Farming Initiative) (Measurement Based Methods for New Farm Forestry Plantations) Methodology Determination 2014* (the Determination).

Detailed instructions and procedural guidance are provided to assist project proponents to undertake a permanent planting or new farm forestry project in accordance with the requirements of the Determination. The Guide includes information on the minimum standards for stratification, in-field data collection, sampling design and the development and validation of allometric functions. The Guide is intended to assist project proponents to meet the standards and conditions required by the Determination and the Clean Energy Regulator.

This Guide is intended to support the Determination, the *Carbon Credits (Carbon Farming Initiative) Act 2010* and associated instruments. It is to be applied consistently with those documents, and it cannot modify or override them.

Proponents should carefully read and understand the information detailed in this document and maintain auditable records.

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Disclaimer

This Guide has been developed to assist project proponents to calculate abatement as required by the *Carbon Credits (Carbon Farming Initiative) (Measurement Based Methods for New Farm Forestry Plantations) Methodology Determination 2014*. While this Guide contains information and guidance required to apply the Determination, project proponents must not use this Guide as a substitution for complying with the requirements in the Methodology Determination.

This Guide will be updated periodically and users should note that some information and guidance may change over time. It is the user's responsibility to ensure that they are using the most recent version of this Guide and any tool/s as required by this Guide.

Before relying on any material contained in this Guide, project proponents should familiarise themselves with the Carbon Farming Initiative (CFI) and obtain professional advice suitable to their particular circumstances.

The Department of the Environment and the Commonwealth of Australia will not be liable for any direct, indirect or consequential loss arising out of, or in connection with, or reliance on, information on, or produced by, using this Guide.

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Definitions

Note The definitions in this Technical Reference Guide are duplicated from the Determination. All terms used in the Technical Reference Guide have the meaning given in the Determination or the *Carbon Credits (Carbon Farming Initiative) Act 2011or Regulations.*

In this Guide:

above-ground biomass means all material in a tree above the soil substrate and includes stem, crown, and attached dead material such as dead branches.

Act means the *Carbon Credits (Carbon Farming Initiative) Act 2011*.

actual location coordinates means spatial coordinates that are collected on the ground using a global positioning system, and that define the location of plots, biomass sample plots and biomass sample trees.

allometric data range means the range between the smallest and largest values of the explanatory variables included within an allometric dataset.

allometric dataset means variables that are:

(a) recorded from biomass sample trees; and

(b) used to develop or validate an allometric function.

allometric domain means the specific conditions under which an allometric function is applicable.

allometric function means a regression equation that describes relationships between biometric measures of specified plant taxa which is used to predict biomass, and may be stratum-specific or region-specific-.

allometric report means a document that describes a project proponent's approach to the development of allometric functions and that meets the requirements set out in section 5.13 of the Determination.

below-ground biomass means all material in a tree below the soil substrate and includes the tap root or lignotuber, and the lateral roots.

biomass means dry, vegetation-derived organic matter.

biomass component means sections of trees that are divided on the basis of structure or form or both.

biomass sample plot means an area of land that occurs within a biomass sample site and is delineated in accordance with Part 5.

biomass sample site means an area of land in which biomass sample plots are located for the purpose of developing a regional function.

biomass sample tree means a tree selected for destructive sampling in order to develop an allometric function.

burnt tree means a tree that has lost biomass in a fire

carbon dioxide equivalent (CO_2e) means the equivalent mass of carbon dioxide for a given mass of greenhouse gas or carbon. For carbon it is calculated by multiplying the mass of elemental carbon by $\frac{44}{12}$.

carbon inventory means an estimation of carbon stocks by sampling and measurements conducted in accordance with Subdivision 5.1.2 of the Determination.

carbon stock means the quantity of carbon, expressed as carbon dioxide equivalent, held within specified components of project forest biomass.

CFI function means a stratum-specific or regional function that was developed in compliance with an existing CFI methodology determination.

CFI Mapping Guidelines means the *Carbon Farming Initiative Mapping Guidelines*, as published from time to time, to be used for mapping project areas and strata within project areas, and available on the Department's website.

CFI methodology determination means a legislative instrument made under section 106 or varied under section 114 of the Act.

clearfelling means a management practice resulting in the felling of all trees in a group of trees.

closing carbon stocks means the carbon stocks, expressed as carbon dioxide equivalent, estimated to be held within specified components of project forest biomass occurring within a stratum at the end of a reporting period.

commencement means the point in time at which preparation of a stratum for planting begins.

commercial thinning means a management practice where:

(a) project trees are thinned;

(b) a harvested wood product is created; and

(c) harvest residue is created.

coppice system means a system where trees are re-established by regrowth from *in-situ* roots or lignotubers.

coarse woody debris CWD means dead woody stem or branch components, or both, that:

(a) have a cross-sectional diameter of more than 25 millimetres;

(b) come from a project tree; and

(c) occur at ground level.

crown means the above-ground tree biomass (including branches, twigs, petioles, and leaves) other than stems.

crown cover means the amount of land covered by the outer limits of the crown (viewed as a horizontal cross-section) of a tree, or collection of trees.

dead material means the non-living above-ground biomass originating from project trees.

declaration date, for a project, means the date on which the declaration of the project as an eligible offsets project under section 27 of the Act takes effect.

disturbance-affected stratum means a stratum that has been subject to a growth disturbance, other than fire—see section 3.6 of the Determination.

explanatory variable means the measured biometric variable used to estimate the response variable—see variable.

farm means:

(a) any tract of land:

   (i) which is used by a person for agriculture; and

   (ii) for which the person holds an estate in fee simple or a lease over the land; or

(b) multiple tracts of land:

   (i) which are used by the same person for agriculture; and

   (ii) for which the person holds an estate in fee simple or a lease over each tract of land; and

   (iii) to which the same methodology determination is applied, regardless of whether those tracts of land are touching.

fire-affected stratum means an area of project forest that has been burnt and that has been dealt with in accordance with Part 3.

fire emissions means emissions of methane (CH_4) or nitrous oxide (N_2O) arising from fire events.

fire event means an occurrence of a fire in a stratum or strata.

forest means land 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.

forest cover—land has ***forest cover*** if the vegetation on the land includes trees that:

(a) are 2 metres or more in height; and

(b) provide crown cover of at least 20% of the land.

fraction remaining —see section 5.27 of the Determination.

fuel emissions means emissions of carbon dioxide (CO_2), nitrous oxide (N_2O), or methane (CH_4) arising from use of fossil fuels to deliver project activities within the project area.

FullCAM means the latest publicly released version on the Department's website of the Full Carbon Accounting Model.

FullCAM Guidelines means the *Guidance for using the Full Carbon Accounting Model (FullCAM) in the Carbon Farming Initiative (CFI) methodologies for the Carbon Credits (Carbon Farming Initiative) (Measurement Based Methods for*

New Farm Forestry Plantations) Methodology Determination 2014 (the Determination), first published and made available on the Department's website on 31 July 2014 and includes any minor amendments to those Guidelines uploaded by the Department to its website from time to time

Greenhouse Friendly^{TM} initiative has the meaning given in the Regulations.

Greenhouse Friendly^{TM} forestry project means an existing forestry project that has been accredited under the Commonwealth Government's Greenhouse Friendly^{TM} initiative.

growth disturbance — means a natural disturbance that may or may not also be a significant reversal, see section 3.5 of the Determination.

$\boldsymbol{GWP_{CH_4}}$ means the global warming potential of methane as prescribed in the *National Greenhouse and Energy Reporting Regulations 2008* as in force at the time that the offsets report was submitted or was required to be submitted, whichever occurs first.

$\boldsymbol{GWP_{N_2O}}$ means the global warming potential of nitrous oxide as prescribed in the *National Greenhouse and Energy Reporting Regulations 2008* as in force at the time that the offsets report was submitted or was required to be submitted, whichever occurs first.

harvest means a management practice involving commercial thinning or clearfelling.

harvest project means a project that consists of project trees established as a new farm forestry plantation or a Greenhouse FriendlyTM forestry project and classified as such under section 2.5 or reclassified under section 4.1.

harvest residue means the project tree biomass that remains on site after a harvest.

infill planting means the planting of project trees to replace mortalities of project trees planted at an earlier time—see section 3.5.

initial carbon stocks means the amount of carbon, expressed in tonnes of carbon dioxide equivalents, estimated to have been held within specified components of the project forest biomass occurring within a stratum on the declaration date.

intended location coordinates means spatial coordinates from a grid overlay used to define the proposed on-ground location of plots and biomass sample plots.

lateral root means the woody material that extends laterally from the tap root or lignotuber of a tree, and which forms part of the below-ground structure of the tree.

litter means fallen dead material originating from project trees that is equal to or less than 25 millimetres in diameter and may include fallen leaves, twigs, bark and small woody stems in various stages of decomposition.

management regime means the spatial extent and timing of events that is undertaken to establish, grow, manage and harvest a harvest project, and includes disturbance events that occur.

management practice has the meaning given in section 4.5

measurement strata means a strata established for the purpose of a carbon inventory.

modelling strata means a strata established for FullCAM modelling.

modelling period means the period, set at 100 years, over which the management regime is modelled in FullCAM.

Note The modelling period is selected to allow for a reasonable period of time in which to run the FullCAM modelling. It is not linked to, or determined by, the permanence period applicable for a sequestration offsets project under the Act.

National Inventory Report means the Australian National Inventory Report, submitted annually under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (KP).

new farm forestry plantation means a plantation:

(a) established on or after 1 July 2010 for the harvest of wood products; and

(b) occupying land that has been cleared of trees and used for agricultural purposes for at least 5 years prior to the establishment of the plantation; and

(c) in an area that, according to the CFI rainfall map, receives the amount of long term average annual rainfall mentioned in an item in the following table; and

(d) occupies the area mentioned in the item.

Farm forestry plantations		
Item	Rainfall	Area
1	400 mm or more	No more than the smaller of the following areas: (a) no more than 100 ha; (b) no more than 30% of a farm.
2	less than 400 mm	No more than the smaller of the following areas: (a) no more than 300 ha; (b) no more than 30% of a farm.

non-commercial thinning means a management practice where:

(a) project trees are thinned;

(b) no harvested wood product is created; and

(c) the debris from thinning is retained on site**.**

non-project forest means forest within the project area that was not established as a direct result of a project carried out under this Determination.

non-project tree means a tree within the project area that was neither planted, nor otherwise established, as a direct result of a project carried out under this Determination.

ortho-rectified aerial imagery means an aerial photograph or satellite image geometrically-corrected for distortion to produce a uniform scale across the image.

permanent planting has the same meaning as in the Regulations.

permanent planting project means a project that consists of project trees established as a permanent planting and classified as such under section 2.5 of the Determination.

permanent sample plot (PSP) means a plot delineated in accordance with Part 5 and from within which measurements are periodically made to inventory carbon stocks.

planting means the planting of project trees from seedlings or seed.

planting finish date means the date that planting of the stratum was completed.

planting start date means the date that planting started within a stratum.

plot means a defined area of land within the project area which can be a temporary sample plot or a permanent sample plot.

plot size means the horizontal area of the land included within the boundaries of a plot or biomass sample plot.

precision standard has the meaning given in section 5.3 of the Determination.

predicted project average carbon stocks (PPACS) means the prediction of the average carbon stocks of a project for a specified management regime over the modelling period, estimated using FullCAM.

predicted stratum average carbon stocks (PSACS) means the prediction of the average carbon stocks of a stratum for a specified management regime over the modelling period, estimated using FullCAM.

predictor measure —see “explanatory variable” and “variable”.

preparation burn means the controlled application of fire within a stratum to assist in the removal or suppression of ground-level vegetation or fire fuel loads.

prescribed weed means any plant that is required by law to be removed.

probable limits of error means the confidence limits for an estimate expressed as a percentage of the mean.

project activity means an activity undertaken within the project area as part of the establishment and management of project forest.

project commencement means the earliest date for which there is documentary evidence that demonstrates, to the satisfaction of the Regulator, that planting has occurred in the project area.

project emissions means emissions of greenhouse gases occurring within the project area as a result of a project activity, from sources within the project greenhouse gas assessment boundary—see section 6.2 of the Determination.

project forest means an area of land covered by a forest of project trees at a specified time or during a specified reporting period.

project forest biomass means the biomass contained within project trees, litter, or CWD.

project removals means removals from the atmosphere of greenhouse gases caused as a result of project activities.

project tree means a tree that has been established through project activities.

regional function means an allometric function developed by or for a project proponent and which has an allometric domain which applies to more than one stratum.

Regulations means the *Carbon Credits (Carbon Farming Initiative) Regulations 2011*.

replant system means a system where trees are re-established by planting or seeding.

root biomass means the biomass of a tree occurring below the level of the soil substrate.

root:shoot ratio (R:S) means the ratio of below-ground biomass to above-ground biomass.

rotation length means the period of time from forest establishment or re-establishment to clearfelling for a harvest project.

sampling plan means a document that identifies the quantity, intended and actual location coordinates of permanent sample plots, biomass sample plots, and the quantity and actual location coordinates of biomass sample trees, within a stratum or the geographic limits of an allometric domain—see Subdivision 5.1.3 of the Determination..

significant reversal means a reversal of the removal of carbon dioxide from the atmosphere if the natural disturbance that caused, or is likely to have caused, the reversal occurred on at least:

(a) 5% of the project area, or project areas in total; or

(b) 50 hectares of the project area or areas;

whichever area is the smaller.

size class means a category of trees delimited by stem diameter, stem cross-sectional area or other biometric measure.

standard margin means a distance from the boundary of the tree planting lines that defines the stratum boundary and is determined in accordance with section 3.3 of the Determination.

stem means the above-ground woody structural supports of a tree that includes the trunk and limbs extending to the crown.

strata means more than one stratum.

stratum means an area in the project area that is determined to have common characteristics in accordance with the requirements of Part 3.

stratum area means the area of land that is occupied by a stratum, expressed in hectares.

stratum identifier means a unique numeric, alpha-numeric, or text string that is used to refer to and identify a stratum in the project area.

stratum-specific function means an allometric function developed by or for a project proponent from an allometric dataset collected exclusively from within a single stratum, to which the function is intended to be applied.

systematic random sampling means an approach to sampling where sampling locations are systematically determined using a randomly placed square grid

t $\boldsymbol{CO_2e}$ means a unit of measurement defined as tonnes of carbon dioxide equivalence (within the meaning of the *National Greenhouse and Energy Reporting Act 2007*).

t-test means a statistical test to determine whether a series of collected observations is suitable for making a prediction about a population.

tap root or lignotuber means a woody part of a tree connected directly to the stem which attaches it to the ground and extends downwards into the soil, with lateral roots extending from it.

target plot size has the meaning given in section 5.21 of the Determination.

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temporary sampling plot (TSP) means a defined area of land that is delineated in accordance with Part 5 and from within which measurements are taken to estimate carbon stocks in a carbon inventory.

test tree means a project tree that has been randomly selected from within a biomass sample plot for measurement as part of the process for validating regional functions or converting stratum-specific functions to regional functions.

tree means a perennial plant that has primary supporting structures consisting of secondary xylem.

tree type means trees that are of the same species and equivalent physical status (live, burnt or dead).

variable means any characteristics, number, or quantity that can be measured or counted which here comprise either non-destructive measurements of trees (explanatory variables) used to estimate their biomass (response variable), based on an allometric function.

weighted least squares method means an algebraic procedure for fitting linear or non-linear regression equations to data in which the contribution of units to the estimate of dispersion is weighted.

weighted residual means the difference between measured and predicted (from a regression equation) values of the response variable (tree biomass) multiplied by a weighting factor, and as calculated in accordance with section 6.60 of the Determination.

Note Other words and expressions used in this Guide have the meaning given by the Act, including:

baseline

crediting period

eligible offsets project

emission

methodology determination

native forest

natural disturbance

offsets project

offsets report

project

project area

project proponent

Regulator; and

reporting period.

Method 1 Identification of project area

1.1 Identification of project area

(1) The boundaries of the project area are required to be delineated in accordance with the CFI Mapping Guidelines and the steps specified below. The CFI Mapping Guidelines are available from the website of the Clean Energy Regulator.

(2) The geographic boundary of the project area is to be delineated through the following steps in sub-methods 1.2 or 1.3.

1.2 Ground survey based approach for project area

(1) Carry out an on-ground survey and plot the boundary of known or proposed tree planting or seeding using a Geographic Positioning System (GPS).

(2) Once spatial data are collected, use Geographic Information System (GIS) software to generate maps that delineate the outer bounds of the tree planting or seeding area, or an area where the tree planting or seeding may take place.

(3) To delineate the project area boundaries, use the GIS to apply a standard margin outside of the limits of the tree planting or seeding area delineated at step (2). This standard margin must be set as one of the following:

- (a) the estimated radius of the crown of a fully mature project tree if that radius can be objectively estimated; or
- (b) if the radius referred to in step (a) cannot be objectively estimated, a default distance of 2 metres.

(4) If application of Steps 3(a) or 3(b) would result in the mapped geographic limits of the project area exceeding the geographic limits of an applicable carbon sequestration right, map the project area to the limits of the applicable carbon sequestration right.

(5) Generate and file hard-copy and soft-copy records of project area attributes, including at a minimum:

- (a) a summary of project area attributes;
- (b) maps of project area;
- (c) GIS shape-files used to delineate project area boundaries;
- (d) dates of creation;
- (e) version numbers; and
- (f) the name(s) of the responsible persons.

(6) The record management system employed needs to allow for effective retrieval of information in the event of an audit.

(7) Ortho-rectified aerial or satellite imagery can be used in support of ground-based surveys in order to delineate the area over which activities to establish project forest have been conducted.

1.3 Imagery-based approach for project area

(1) Subject to (4), as an alternative or adjunct approach to the approach outlined in Method 1.2, ortho-rectified aerial or satellite imagery covering the project area may be used to delineate the project area through the steps specified in this Method.

(2) Obtain ortho-rectified aerial or satellite imagery of the project area with a horizontal accuracy in accordance with CFI Mapping Guidelines and with pixel resolution no greater than 2.5 metres (reflecting the pixel resolution of spot data used in the CFI Mapping Tool).

(3) After the imagery specified in step 2 has been obtained:

   (a) digitise the imagery of the relevant land area;

   (b) incorporate it into a GIS; and

   (c) undertake steps (3) to (5) from Method 1.2 Ground-based survey approach.

(4) An imagery-based approach can replace the need for ground-based survey only in circumstances where the imagery is of sufficient quality and resolution to allow the clear identification of the limits of activities to establish project forest.

Method 2 Stratification

2.1 Division of project area into strata

(1) Sub-units of land area, referred to as strata, must be identified within the boundary of the project area defined in Method 1.

Note A stratum is the base land unit used to calculate estimates of carbon stocks occurring within the project area. Strata are also known as Carbon Estimation Areas.

(2) In this methodology two types of strata are used:

(a) measurement strata—used for carbon inventories; and

(b) modelling strata—used for modelling with FullCAM.

(3) All projects must define measurement strata.

(4) All projects that use FullCAM for modelling and estimating the PPACS and/or for estimating root:shoot ratios must also define modelling strata.

(5) Measurement and modelling strata may have the same geographic extent, or they may cover different areas, depending on the project conditions and the stratification approach adopted for Measurement strata.

Note For projects that involve harvesting, the Modelling strata are used to estimate the PPACS, and the Measurement strata are used to estimate actual carbon stocks and determine when the PPACS has been reached.

(6) Before the submission of the first offsets report, the project proponent must define in the project area one or more strata in accordance with the CFI Mapping Guidelines and in compliance with Method 3 and this Method.

(7) The project proponent may define new strata at any time provided they comply with Method 3 and this Method.

(8) New strata may:

(a) be excised from existing strata;

(b) replace existing strata; or

(c) cover land within the project area not previously included within strata boundaries.

(9) If the boundaries of a stratum are redefined, they must be redefined in accordance with the requirements set out in Method 3.5.

2.2 Minimum requirements for a stratum

(1) A stratum must have been planted with one or more species of project trees.

(2) project proponents may also define a stratum by distinguishing parts of the project area based on any of the following:

(a) project tree age;

(b) tree species;

(c) observed or measured growth trends;

(d) growing regions;

(e) climatic conditions;

(f) soil types;

(g) disturbance history;

(h) land management units;

(i) management regime; or

(j) any other characteristics that may be likely to influence project tree growth.

2.3 Additional requirements for measurement strata

(1) In order to undertake a carbon inventory under Method 5, a measurement stratum must satisfy the requirements and processes specified in Method 3.

Note Measurement strata need not be delimited by a single continuous border and can consist of spatially separate 'cells'. For example, a stratum could include one or more cells on a farm in one area and other cells on another farm in another area.

(2) Any areas greater than 10 hectares in size that are known to have been subject to a major disturbance event which is likely to have a long-term influence on carbon stocks must be defined as a unique stratum by applying Method 4.

2.4 Additional requirements for modelling strata

(1) Modelling strata are required to use FullCAM to estimate root:shoot ratios (Method 11.5) as well as to estimate the average carbon stocks of harvest projects.

(2) All projects that nominate harvesting are required to establish modelling strata.

(3) All projects that use a root:shoot ratio to estimate belowground biomass are required to establish modelling strata.

(4) Modelling strata may have different boundaries from measurement strata.

(5) For accurate modelling using FullCAM it is a requirement that the modelling strata are uniform in terms of factors affecting tree and forest growth.

(6) Modelling strata must only contain land area which consists exclusively of project trees.

(7) As a minimum, project proponents must define modelling strata based on the following:

(a) tree species or community of tree species:

(i) only one tree species or community may be present in a modelling stratum;

(ii) these species must reflect a tree species identified in FullCAM. For example, this could be Mixed Species Environmental Planting or a single species;

(b) tree age;

(i) all project trees in a modelling stratum must have been established during a single planting period;

(c) management regime;

(i) the timing and extent of management practices are the same within a modelling stratum, including weed control, fertilizer application, pruning, thinning, harvesting, fire, harvest residue management (e.g. chopper rolling), and re-planting/seeding/coppice;

(d) disturbance history; and

(i) areas affected by a disturbance event require a separate modelling stratum to be created by applying Method 4;

(e) site attributes;

(i) which may include soil or climatic region.

(8) Modelling strata must have a single modelling point located approximately in the centre of each modelling stratum.

Method 3 Delineating a stratum

3.1 Delineating stratum boundaries

(1) This Method sets out the processes for:

(a) delineating the boundaries of a stratum within the project area; and

(b) deriving an estimate of the stratum area.

(2) A project proponent must delineate the boundaries of the stratum and derive an estimate of stratum area using the following steps:

3.2 Ground survey-based approach for stratum

(1) Carry out an on-ground survey and use a GPS to plot the outer edge of the project trees to be included within the stratum.

(2) The outer edge of project trees is delineated by the centres of the stem bases or the centres of trees crowns to be included in the stratum. Any exclusion areas must not be included as required by the CFI Mapping Guidelines.

(3) Once the survey data are collected, use GIS to generate maps and shape-files delineating the outer limits of the stems of the project trees.

(4) To delineate the boundary of the stratum, use GIS to apply a standard margin to circumscribe the outer limits of the stems of project trees.

(5) The standard margin must be applied consistently to a stratum for the duration of the project and must be set as one of the following:

(a) the estimated radius of the crown of a fully mature project tree if that radius can be objectively estimated; or

(b) if the radius specified in step (a) cannot be objectively estimated, a default distance of 2 metres; or

(6) If application of Steps 5(a) or 5(b) would result in the mapped geographic limits of the stratum:

(a) overlapping the geographic limits of a second stratum—map the stratum area to a point equidistant between the two strata along the length of the area where the overlap would otherwise have occurred; or

(b) exceeding the geographic limits of the project area—map the stratum area to the limits of the project area.

(7) Generate and retain hard-copy and soft-copy records of the area attributes of each stratum , including as a minimum:

(a) summary of the area attributes;

(b) maps;

(c) GIS shape-files delineating boundaries;

(d) references to dates of creation;

(e) version numbers; and

(f) the name(s) of responsible persons.

(8) All relevant shape-files, spatial data and other hard and soft copy records must be managed with a suitable system in a form that allows for retrieval and review by an auditor.

(9) Areas of land without project trees within the boundary of a stratum must be mapped as exclusion areas as required by the CFI Mapping Guidelines. Under the Guidelines, exclusion areas include areas that cannot or will not be planted, e.g. roads, firebreaks, and pockets of remnant woody vegetation (native or planted).

(10) Ortho-rectified aerial or satellite imagery can be used in support of ground-based surveys in order to delineate the area over which activities to establish project forest have been conducted.

3.3 Imagery-based approach for stratum area

(1) Subject to (4), as an alternative or adjunct approach to the above, ortho-rectified aerial or satellite imagery covering the stratum may be used to delineate the stratum through the processes set out in this sub-method.

(2) Obtain ortho-rectified aerial or satellite imagery of the stratum with:

(a) a horizontal accuracy in accordance with CFI Mapping Guidelines; and

(b) pixel resolution no greater than 2.5 metres (reflecting the current pixel resolution of spot data used in the CFI Mapping Tool).

(3) The imagery of the relevant land area must be digitised and incorporated into a GIS; then steps (4) to (9) from Method 3.2 must be undertaken.

(4) An imagery-based approach can replace the need for ground-based survey only in circumstances where the imagery is of sufficient quality and resolution to allow the clear identification of the limits of stratum establishment activities.

3.4 Requirements for revisions of stratum boundaries

(1) Where a stratum or a stratum boundary is redefined, revised boundaries must comply with the requirements for delineating stratum boundaries set out in Method 3.2 or 3.3.

(2) If a revision, or cumulative revisions, of the boundaries of a stratum change the stratum area by more than 5% between any reporting periods then:

(a) a carbon inventory which includes the revised stratum area must be conducted; and

(b) the date of the carbon inventory must be no earlier than 6 months before the end of the reporting period.

(3) Where a stratum area is reduced to zero through redefining stratum boundaries in accordance with Method 3 and 4, step (2) does not apply.

(4) Once a stratum is defined within a project area and reported within an offsets report, the stratum identifier associated with that stratum must continue to be reported in subsequent offsets reports as having been associated with the project area even where:

  (a) the stratum area is reduced to zero through redefining the stratum boundary; or

  (b) the stratum is redefined so that it is entirely replaced with other strata.

(5) Where step (4) applies:

  (a) values of zero must be recorded against the stratum identifier for the closing carbon stocks and the standard error for closing carbon stocks; and

  (b) these zero values must be applied for the purposes of calculating the carbon stock change for a stratum and standard error for carbon stock change for a stratum.

Note A project proponent must generate and keep records in relation to each stratum in accordance with the requirements set out in Part 7 of the Determination.

Method 4 Dealing with disturbance events

4.1 Natural disturbances and growth disturbances

(1) The project proponent must identify and record the occurrence of natural disturbances that occur within a stratum.

Note When a natural disturbance that is also a significant reversal has occurred, the proponent is required to meet their obligations as outlined under section 81 of the Act, which include provisions for notifying the Regulator and re-establishing carbon stocks. Examples of events include floods, fires, droughts, pest attacks, diseases, and events that may cause a significant reversal under the Regulations.

(2) If an event occurs that is likely to affect the growth characteristics of the whole or part of a stratum and that stratum has been previously reported in an offsets report (a ***growth disturbance***) the processes outlined in this method must be applied.

Note A growth disturbance is a natural disturbance that may or may not also be a significant reversal. The growth disturbance is still required to be identified and mapped, but may not necessarily exceed the thresholds to be considered a significant reversal under the Regulations.

(3) The proponent must conduct an aerial- or ground-based survey, or a combination of the two, to estimate the extent to which strata within the project area have been affected by the disturbance event.

(4) One of the two approaches below must be undertaken depending on the estimated size of the area affected by the disturbance event.

4.2 Growth disturbance has affected more than 10 hectares of project trees within a stratum

(1) If the growth disturbance has affected more than 10 hectares of project trees within a stratum the process outlined in this sub-method must be undertaken.

(2) The boundary of the disturbed area must be mapped within 6 months of the date on which the disturbance event occurred using a ground-based survey employing GPS or interpretation of ortho-rectified aerial or satellite imagery collected over the disturbed area after the disturbance event.

(3) A combination of ground-based survey employing GPS and ortho-rectified aerial imagery may also be used.

(4) The disturbed area must then be separated as a unique stratum referred to as a disturbance-affected stratum, or in the event that the disturbance has been a fire event, a fire-affected stratum.

(5) Where the growth disturbance has been a fire, a carbon must be inventoried both within the newly created fire-affected stratum and the undisturbed portion of the stratum from which the fire-affected stratum has been excised. This process must be completed within 12 months from the date of the fire.

(6) An offsets report must be submitted to the Regulator within 18 months of a disturbance event of this scale and, in the case of fire, the offsets report must include estimates of CH_4 and N_2O emissions arising from the event and subtract these from the abatement estimate.

4.3 Disturbance event has affected 10 hectares or less of project trees within a stratum

(1) If the disturbance event has affected 10 hectares or less of project trees within a stratum the following process outlined in this sub-method must be undertaken.

(2) The boundary of the disturbed area must be mapped within 6 months of the date on which the disturbance event occurred using ground-based survey employing GPS or interpretation of ortho-rectified aerial or satellite imagery collected over the disturbed area after the disturbance event.

(3) A combination of ground-based survey employing GPS and ortho-rectified aerial imagery may also be used.

(4) The proponent can then choose either to:

- (a) separate the affected area into either a disturbance-affected stratum or a fire-affected stratum (as per sub-method 4.2 above); or
- (b) continue to treat affected and unaffected areas as belonging to a single stratum. Where this option is exercised, Proponents continue to measure and model as per their pre-disturbance schedule.

(5) Due to potential carbon maintenance obligations being linked to the project area, Proponents must not reduce the area of disturbance-affected stratum, or fire-affected stratum, on the basis of project tree losses over time.

(6) The project proponent must, within 6 months after the growth disturbance, delineate the boundaries of the land occupied by project trees affected by the disturbance.

4.4 Infill planting

(1) If project trees die after planting, infill planting may be undertaken up until 36 months from the planting finish date for the stratum.

(2) The death of the project trees is not treated as a growth disturbance if infill planting is undertaken after the project trees have died.

Note Infill planting is a planting for the purpose of replacing project trees that have died within the time period specified in step 1.

Method 5 Carbon Inventory

5.1 Principles of carbon inventory

(1) A carbon inventory is conducted whenever a current estimate of project carbon stocks is required for an offsets report for a reporting period.

(2) To undertake a carbon inventory a network (grid) of permanent sample plots (PSPs) or temporary sample plots (TSPs) must be established and measured in each stratum.

(3) A carbon inventory can be undertaken with either PSPs or TSPs, or both PSPs and TSPs.

(4) If biomass sample trees are required for destructive sampling then TSPs are required whether or not PSPs are also established.

(5) In the absence of a disturbance event, project proponents can choose to report the current carbon stocks for a stratum as being the same as the carbon stocks for the stratum in the previous offsets report. Similarly, the standard error can be reported as that in the previous offsets report.

(6) When undertaking a carbon inventory sample plots are established and measured in each stratum as follows:

- (a) A network of PSPs is established and measured. In subsequent carbon inventories, these PSPs are re-measured.
- (b) A network of TSP locations is established to select any biomass sample trees (destructive sample trees) required for developing or validating allometric functions.
- (c) Estimates of strata carbon stocks and project carbon stocks are calculated from assessments of the PSPs and TSPs.
- (d) If the estimate of project carbon stocks is not sufficiently precise (i.e. the specified probable limits of error are not achieved) then a second network of TSPs must be established and assessed.

Permanent sample plots (PSPs)

(7) PSPs are required to be marked so they can be re-located and re-measured in successive carbon inventories. Because PSPs are to be re-measured it is important that they are not disturbed during the carbon inventory, for example:

- (a) by taking trees for destructive sampling (biomass sample trees) for developing or validating allometric functions; or
- (b) by taking samples for assessing litter or coarse woody debris.

Temporary sample plots (TSPs)

(8) TSPs are not intended for re-measurement. The purposes of a TSP are:

(a) to be a source of biomass sample trees for developing and validating allometric functions;

(b) to assess carbon stocks data used to estimate strata-level and project-level carbon stocks in a carbon inventory.

5.2 Project carbon inventory procedures

(1) Carbon inventory for a project involves undertaking the following processes in each stratum:

(a) Generate a contemporary map of the stratum and a contemporary stratum area estimate (Methods 2 and 3).

(b) Document a sampling plan (Method 6) describing the number and location of any PSPs and TSPs to be established and assessed within the stratum (Methods 7 and 8).

(c) Establish and assess all PSPs and TSPs (Method 8). This Technical Reference Guide refers to PSPs and TSPs collectively as plots.

(d) Develop stratum-specific functions as per Methods 11 to 13, or select appropriate regional functions (Method 10) or existing CFI functions and perform the validation checks detailed at Method 13.

(e) Apply the allometric functions developed or validated at Step 1(d) to estimate the biomass content of project trees within each Plot.

(f) If electing to account for carbon in the litter and CWD pools, assess the biomass within these pools around each plot (Methods 15 and 16).

(g) Convert the biomass estimates derived at Steps 1(e) and (f) to estimates of carbon stocks within each plot using Equations 4.1 to 4.12 in accordance with the Determination.

(h) Calculate the mean of the carbon stock estimates for all plots occurring within the stratum and multiply by the stratum area to derive the closing carbon stocks for the stratum (Equations 3.5 and 3.3) in accordance with the Determination).

Method 6 Developing and documenting a sampling plan

Note Proponents are required to develop and document a sampling plan whenever inventorying carbon (Method 5), and whenever an allometric function is to be developed (Method 10), or validated (Method 13).

6.1 Minimum requirements of a sampling plan

(1) Proponents are required to develop and document a sampling plan which includes:

(a) a description of the activity (carbon inventory, developing an allometric function, validating an allometric function, or combinations of these) to which the sampling plan relates;

(b) the dates over which activity is to be conducted; and

(c) the sampling requirements for the type of activity the sampling plan relates to at 6.2 to 6.4.

6.2 Requirements for sampling plans for carbon inventories

(1) When the sampling plan relates to a carbon inventory, the following details must be included in the sampling plan:

(a) A description of the stratum that the sampling plan refers to, including the stratum identifier;

(b) Hard and soft-copy maps showing the geographic boundaries of the stratum and the grid overlay;

(c) The plot size to be applied within the stratum (Method 8);

(d) A description of plot shape;

(e) Details of the sampling grids for plot location (Method 7a), including the grid size (hectares) and orientation (random angle, Figure 2) for each grid;

(f) Maps showing the position of all PSPs and TSPs;

(g) The location coordinates of all PSPs and TSPs. This should include the intended location coordinates (from the sampling grid) and the actual location coordinates of the Survey marks; and

(h) Details of any displacement between the intended and actual location coordinates of PSPs and TSPs and, where displacement exceeds thresholds prescribed at Method 8, details of the corrective measures that were taken (i.e. relocation and reassessment of the plot).

6.3 Sampling plan requirements for development of stratum-specific functions & validating allometric functions

(1) When the sampling plan relates to the development of stratum-specific functions and/or validating allometric functions, the following details must be included in the sampling plan:

(a) A description of the stratum that the sampling plan refers to, including reference to the stratum identifier;

(b) Hard and soft-copy maps showing the geographic boundaries of the stratum;

(c) Details of the selection process for biomass sample trees, including ranked size classes for explanatory variables and the number of project trees within each size class;

(d) Maps showing the position of TSPs from which biomass sample trees are selected; and

(e) Spatial coordinates for the location of biomass sample trees, as collected in the field using GPS.

6.4 Sampling plan requirements for development of regional allometric functions

(1) When the sampling plan relates to the development of regional allometric functions, the following details must be included in the sampling plan:

(a) A description of the intended allometric domain to be sampled, including geographic region and species of tree(s);

(b) Details of the selection process for biomass sample trees, including ranked size classes for explanatory variables and the number of trees within each size class;

(c) Hard and soft-copy maps showing the location and extent of biomass sample sites, biomass sample trees sampled (Methods 11 and 12), the grid overlay applied to the biomass sample sites defining the location of biomass sample plots; and

(d) Spatial coordinates describing the location of any biomass sample sites, biomass sample plots and biomass sample trees as generated offsite and as recorded onsite using GPS.

Method 7 Determining the location and shape of plots

7.1 Plot location

(1) All plots must be located at the grid intersections of randomly-placed and oriented grid overlays. All grid intersections represent an intended plot location.

Note This is known as 'systematic sampling with a random start' or 'systematic random sampling'.

(2) Each stratum must contain at least one and may contain up to three grid overlays. This is limited to one grid overlay for PSPs and up to two grid overlays for TSPs.

(3) It is recommended that any grid overlay be applied to the whole project area not just an individual strata within the project area.

Note If the strata are widely dispersed (for example they are in different regions) proponents may prefer to establish separate s for individual strata or groups of strata.

(4) Grid overlays must be established as follows:

(a) Using a contemporary map of the strata boundaries (Method 3), use a GIS to establish a grid over the map of the stratum (or project area) through systematic random sampling (refer Figure 2 for illustration);

(b) Each grid overlay must be composed of square cells;

(c) The grid overlay size (hectares) is determined by the number of plots required and the area of the stratum or project being sampled. Refer to Method 8 for procedures to determine the total number of plots (PSPs and TSPs) in a stratum or project;

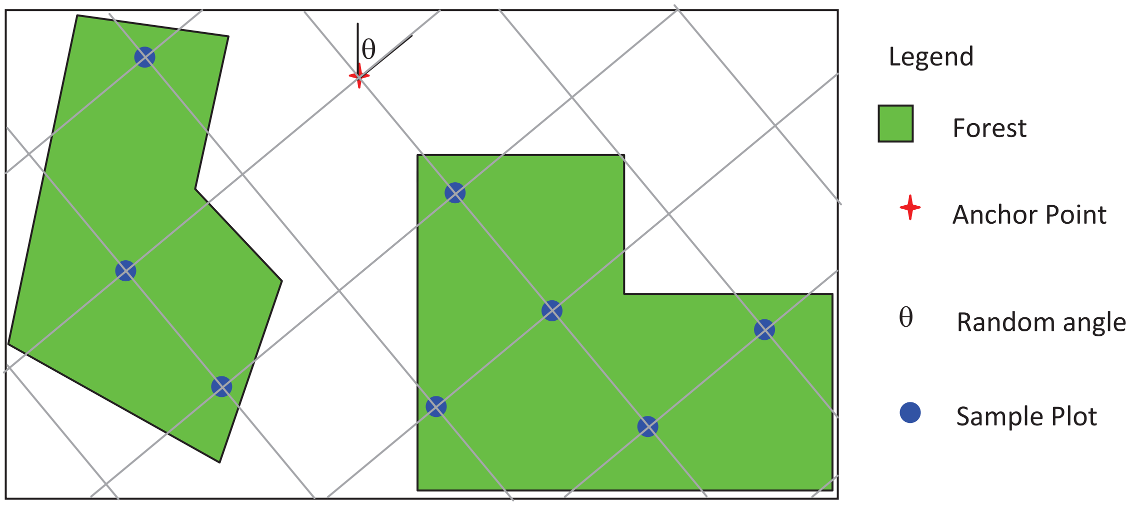
(d) An anchor point for the grid overlay must be obtained by randomly selecting an Easting and a Northing coordinate within the ranges of Easting and Northing coordinates for the stratum or project. The Easting and Northing coordinates must be from the Map Grid of Australia (MGA94) or another Australian standard;

(e) The orientation of the grid must be determined by randomly selecting an angle between 0 and 89 degrees;

(f) Software products, such as planning tools for forest assessment, may be used for steps 4(a) to (e);

(g) Plots must be established only at the grid intersections.

(5) All plots (PSPs and TSPs) located by a grid must be assessed.



(6) Figure 2. Example of systematic random sampling for plot location

7.2 Plot shapes

Note Refer to Method 8.3 for assessing plots and minimum plot size.

(1) Circular plots are established so that the location coordinates define the centre of the plot and the boundary is defined by a radius (see Figure 3 below).

(2) Square/rectangular plots are established so that the location coordinates define a constant position relative to each plot (e.g. the centre of the plot).

(3) Plots in belt plantings (belt plots) are created as rectangular plots and are established as follows (see Figure 4 below):

(a) A centre line is established that passes through the location coordinates and is perpendicular to the orientation of the belt at that point.

(b) The lines defining the ends of the belt plot are parallel to the centre line of the belt.

(c) The width of belt plots is measured along the centre line between the stratum boundaries. Note that the stratum boundary extends out from the outer limits of tree planting on either side of the belts by a distance equal to the standard margin.

(d) Plot length is calculated as the plot size divided by the plot width.

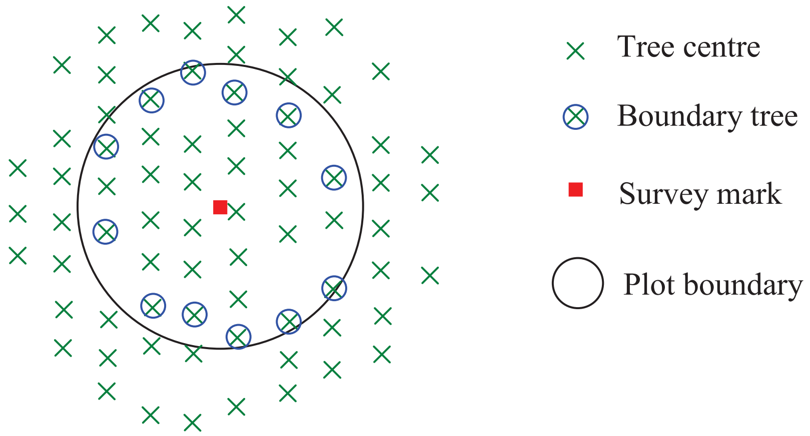
(4) Nested plots of any plot shape may be established. Nested plots are two or more plots with the same location coordinates. As such:

(a) Nested circular plots will have the same centre (concentric circles);

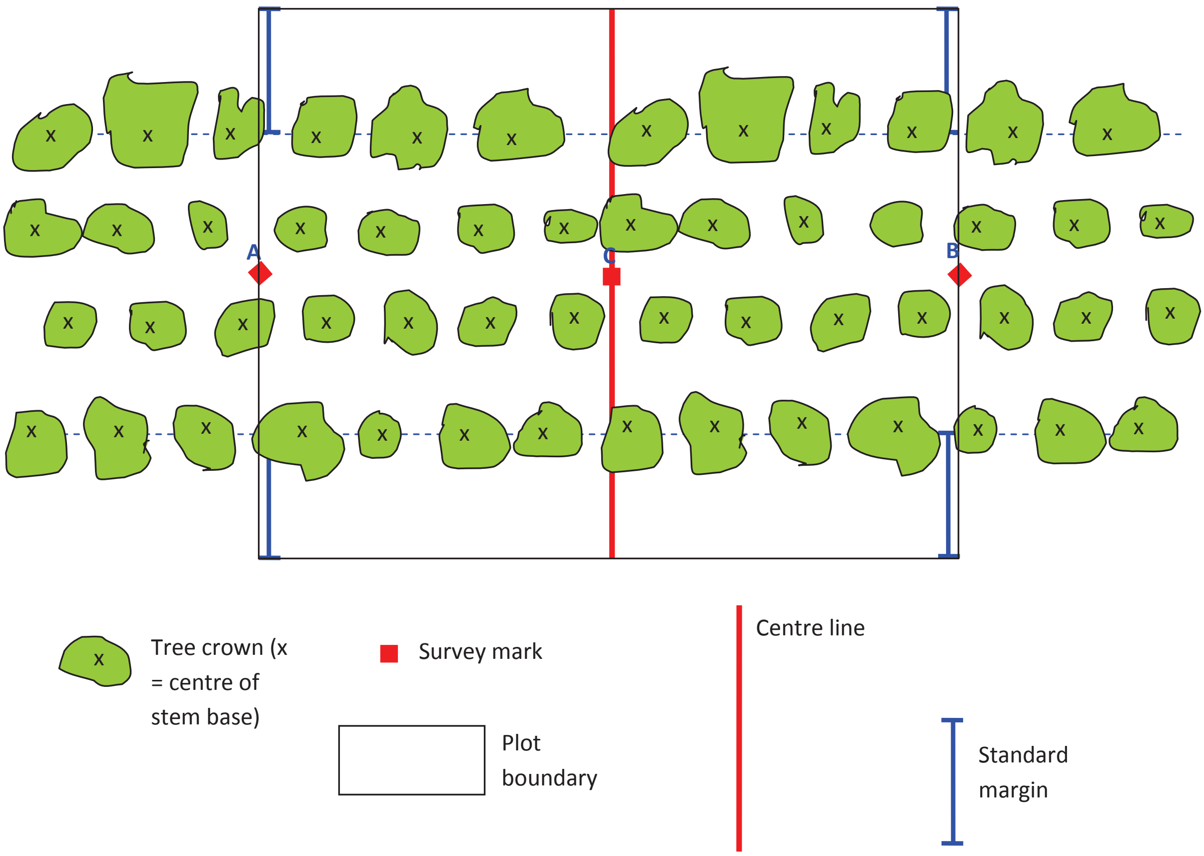
(b) Nested square/rectangular plots will also have the same centre if the location coordinates define the plot centre; and

(c) Nested belt plots will have the same centre line and same width but will vary in length.

(5) Any plot shape may be a nested plot but must have the same grid location as the primary plot.



(6) Figure 3. Example of a circular plot in a planting. Boundary trees at the ends of rows in the plot can be marked (e.g. with flagging tape) to indicate which trees are in the plot. The survey mark is retained as a permanent mark for the plot centre.



(7) Figure 4. Example of a belt plot in a belt planting with four rows. Distance AC = Distance BC = half plot length. Plot length (AB) is calculated to give the required plot area.

Method 8 Establishing and assessing plots

8.1 Minimum number of plots

(1) Table 2 specifies the minimum number of sample plots to be established for a project.

Note This is the minimum required and plots must be distributed uniformly throughout the project area. For example, if the project area is 30 ha, at least 1 plot per ha must be established in each and every stratum; some strata could have more than 1 plot per ha.

(2) Table 2. Minimum number of plots in the project area to be initially established.

Project area	Minimum number of plots
≤ 30 ha	30
> 30 – 100 ha	50
> 100 – 1,000 ha	70
> 1,000 – 10,000 ha	100
> 10,000 ha	200

Note The specifications in Table 2 are based on requirements in the New Zealand Field Measurement Approach (NZ Gov., 2011) (FMA). However, the number of plots for any project area has been increased from the minimum required in the New Zealand FMA based on extensive local experience undertaking carbon inventory of small- and large-area plantings (e.g. by Forest Products Commission, WA).

8.2 Precision standard

(1) In the Determination the precision standard is defined by the probable limits of error (PLE) for the estimate of project carbon stocks.

Note PLE is a term, common in forestry that refers to the confidence limits for an estimate expressed as a percentage of the mean, e.g. see Goulding and Lawrence, 1992.

(2) For this methodology the precision standard is that the PLE for the estimate of the closing carbon stocks for a project is ≤10% at the 90% confidence level.

(3) The PLE for the estimate of the closing carbon stocks for a project is calculated from Equation 6.1.

(4) Table 2 specifies the minimum number of plots that must be initially established in a project. However, more plots may be required to achieve the desired precision standard for the estimate of project carbon stocks.

(5) If the precision standard is not met proponents have two options as follows.

(a) **Option 1:** Calculate and report the estimate of project carbon stocks for the reporting period at the lower 90% confidence limit.

(i) This option is only available if the PLE is ≥ 20%, i.e. the PLE falls between 11% and 20%.

(ii) Under Option 1, the project carbon stocks for the reporting period is calculated and reported from Equation 2.9. However, projects must achieve the precision standard (PLE ≤ 10%) for a reporting period at least once every 5 years.

(b) **Option 2**: Assess more plots (following Methods 5-7) until the precision standard is met.

(i) Under Option 2, a means of estimating how many additional plots should be assessed to achieve the precision standard is required. One option is to apply the methodological tool developed for Clean Development Mechanism afforestation and reforestation projects to estimate the number of sample plots required (UNFCC, 2009, Pearson, *et al*. 2005). The estimate will be approximate if the plot size is not constant for all strata. Alternatively, an approximate is provided by Equation 6.2, applied as follows:

(A) From the plots that have been assessed, estimate the closing carbon stocks for the project (Equation 2.7) and the PLE for that estimate (Equation 6.1).

(B) Use Equation 6.2 to estimate the number of plots required to achieve the precision standard. However, note the assumption that any increase in the number of plots required for the project will be applied *pro rata* across all strata. When calculating how many additional plots to assess it is advisable to inflate the estimate by at least 20% to ensure that enough additional plots are assessed.

8.3 Assessing plots

(1) All plots must be assessed as follows.

(2) The intended location coordinates for all plots must be uploaded into a GPS, which is then used to navigate to those locations.

(3) The locations must be marked with a survey mark that is fire- and flood-resistant, allowing for return visits up to five years later.

(4) The survey mark must indicate:

(a) The centre of circular plots (Figure 3);

(b) The centre of square/rectangular plots or some other point, e.g. the south-western most corner, depending on the system for plot establishment;

(c) A point on the centre line of belt plot which is, either the point navigated to using a GPS or a survey mark on the centre line of the belt plot (Figure 4).

Note Procedures (a) – (c) above will provide for accurate re-establishment of any plot boundary in the field.

(5) Plots must be established according to the intended location coordinates as shown on the GPS in the field, without any deliberate positioning of plots by field crews with reference to, for example, planting lines, inter-rows, compartment breaks, unplanted land, strata boundaries, or for any other reason.

(6) Where the plot location falls close to stratum boundaries, Method 9 may apply.

(7) Plots must be a pre-defined size within a stratum, which is to be documented in a sampling plan; the minimum plot size is 0.02 hectares.

(8) The plot size may vary between strata.

(9) Plots must be assigned a unique identifier.

(10) When measuring or re-measuring plots the following process must be followed:

(b) The coordinates of the survey mark must be logged with a GPS and recorded as the actual location coordinates.

(c) Then a displacement comparison must be conducted as follows:

(i) the intended location coordinates generated at Method 7 and documented in the sampling plan (Method 6), must be compared with the actual location coordinates recorded using GPS at step (5).

(ii) The variation between these is to be no greater than ± 10 m (referred to as location tolerance).

(iii) If the location tolerance is not achieved, the proponent must relocate the plot and repeat steps 10(c)(i) and (ii) until the plot location tolerance is met.

(iv) All displacement comparisons, including any requirement to reposition plots, must be documented in the sampling plan.

Note Where the location tolerance is exceeded for any plot, any data collected from that plot may not be included in any of the calculations in the Methodology Determination.

(2) When measuring or re-measuring plots the following information must be collected (at a minimum):

(a) The actual location coordinates;

(b) The result of the displacement comparison;

(c) plot identifier and date of assessment;

(d) Dimensions of the plot, so as to calculate the land area sampled;

(e) Whether the plot falls wholly within the stratum boundary, or falls across the stratum boundary —in which instance Method 9 must be applied);

(f) Measures of explanatory variables for each project tree so as to allow estimation of biomass using allometric functions developed and/or validated through Methods 11-13; and

(g) Where proponents elect to account for carbon contained within the litter and CWD pools, these must be assessed as per Methods 14 and 15.

(3) Where no project trees occur within the bounds of a plot, this should be noted and the plot is recorded as having zero carbon stock. Any zero carbon stock values that are recorded in this way must be included in the calculations in the net abatement calculations in the Determination. Non-project trees are not to be assessed, or included in any calculations of carbon stocks for the project.

(4) Proponents must retain quality assurance records that identify the type of equipment used to measure explanatory variable, and demonstrate calibration of the equipment, and document errors, and checks and corrections for errors that were applied during measurement.

Method 9 Dealing with plots that overlap edges or corners of reforestation areas

9.1 Introduction

(1) Some plots will extend across the edge of a stratum boundary.

(2) Where this is the case, the appropriate Sub-Method 9.2, 9.3 or 9.4 must be applied.

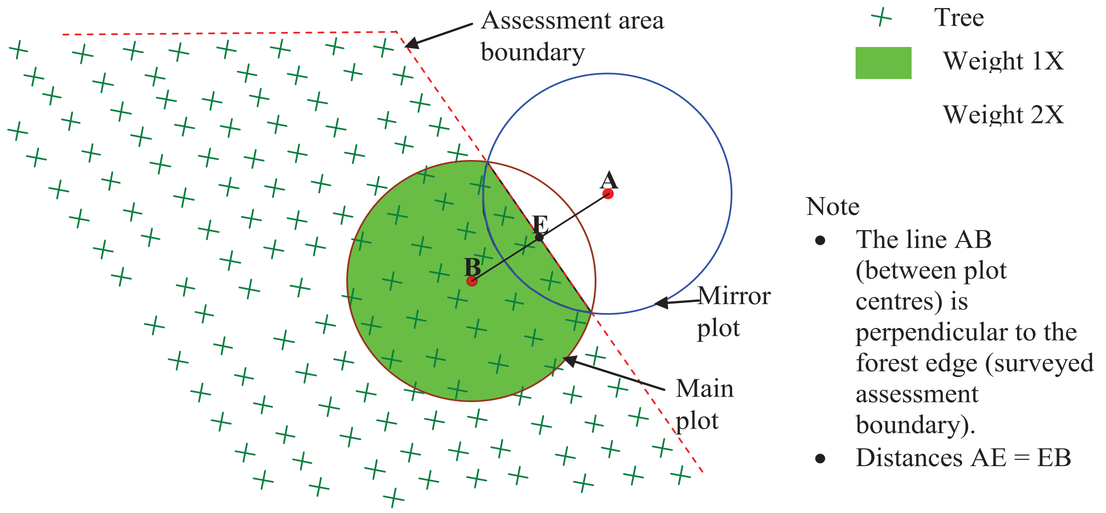
Note An inappropriate solution in this situation would be to move the plot centre away from the edge until the plot is wholly contained within the stratum. However, this will bias the sampling against edge trees, i.e. trees growing near the edge of the strata will have lower probability of being selected than other trees. The bias introduced will be greater in small area plantings and long thin plantings with a larger perimeter to area ratio. This is typically the case in farm forestry plantations.

9.2 Edge plots - mirage method

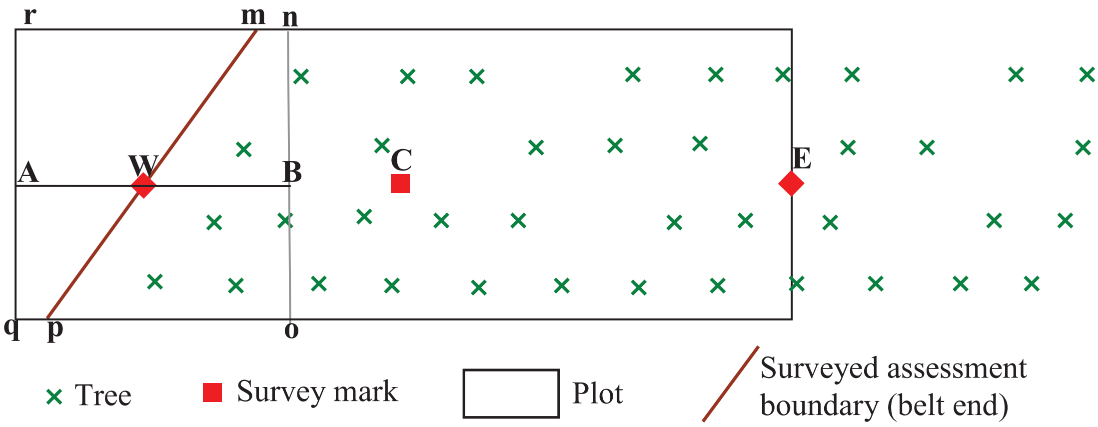
(1) To prevent "edge-effect" bias the mirage (mirror) method must be applied as follows.

Note The mirage method was proposed in the German language by Schmid-Haas in 1969. For English language descriptions of the mirage method see Loetsch *et al*. (1973a), Beers (1977), AGO (2002) or Mason (2005). For statistical analysis to prove the mirage method is unbiased sampling see Gregoire (1982) and Gregoire and Scott (2003).

(2) Application of the mirage method for circular plots is shown in Figure 5 and for belt plots in Figure 6.



(3) Figure 5. Mirage method for circular plots.



Note: C = plot centre; distances AW = WB; areas mnop = pqrm; trees in shaded area mnop have 2X weighting

(4) Figure 6. Mirage method for belt plots.

(5) The mirage method involves:

(a) measuring all trees within the plot and stratum boundary, and recording those trees within a mirror image (mirage) reflected on the stratum boundary. The 'mirror trees' are given double weighting by including the measurements of them twice in all calculations, e.g. for stocking, basal area, and biomass.

(b) Note that the stratum boundary is located a distance equal to the standard margin from the edge trees.

9.3 Corner plots - direct weighting method

(1) Where the plot boundary extends over the corner of a stratum, (i.e. there is more than one edge in the plot overlapping the plot boundary), the direct weighting method may be applied.

Note It is theoretically possible to apply the mirage method to plots that extend across a corner (two edges), but it is very difficult to implement in the field, particularly if the corner is not a right angle as is commonly the case. In rare cases, there may be more than two edges in the plot, e.g. Figure 7. If there is more than one edge in the plot, the direct weighting method, although not bias free, is the least biased of alternative methods (Beers, 1977; Loetsch et al., 1973b).

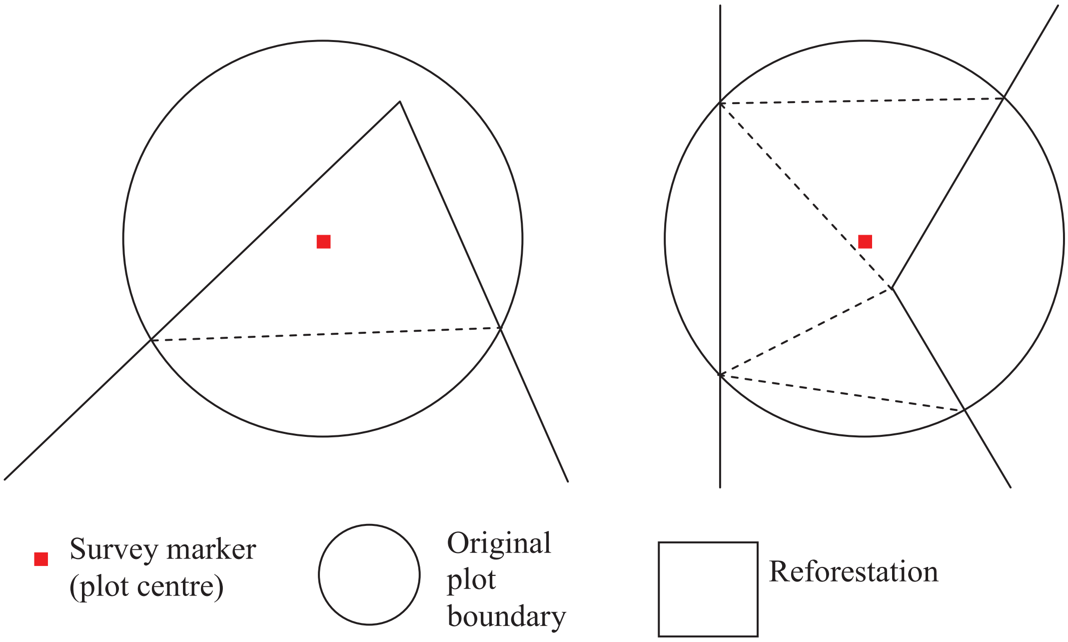
(2) Under the direct weighting method all trees are weighted equally by the ratio $A_{plot} / A_{reforestation}$ where A_{plot} is the plot area and $A_{reforestation}$ is the area of the plot which falls within the stratum.

(3) Alternative methods for calculating the reforestation (stratum) area in the plot are:

(a) Taking sufficient measurements in the field to calculate the area; or

Note For example, divide the reforestation area into triangles and/or parts of a circle (Figure 7), and measure the distances required to calculate the areas of the parts.

(b) Using a GIS if accurate coordinates for the plot centre are available (for example, from differential GPS (DGPS)) and the stratum boundary is also captured in a shape file.



(4) Figure 7. Examples of situations where the direct weighting method should be applied. Dotted lines indicate the division of the stratum area falling within the plot (reforestation area) into triangles and circle segments for area calculation.

9.4 Conservative assumption method

(1) As an alternative to Sub-Methods 9.2 and 9.3, proponents may choose to only measure trees which fall within the plot and stratum, and estimate the carbon stocks using the full plot area.

(a) This will result in a conservative estimate of carbon stocks in edge plots.

(b) This approach will be best suited for square/rectangular plots, where the mirage method is difficult.

Method 10 Applying allometric functions

10.1 Introduction

(1) The use of allometric functions to estimate biomass and carbon in forests is a well-established practice (e.g. AR-AM0011; Parresol 1999; Snowdon *et al.* 2002; Specht & West 2003).

(2) A species-specific allometric function is used to predict biomass from project tree dimensions for either:

(a) Total tree biomass, if root biomass of biomass sample trees was assessed directly through destructive sampling and Method 11.6 is applied, or

(b) Above-ground biomass, if root biomass of biomass sample trees was assessed with a root:shoot ratio and Method 11.7 is applied.

(3) Proponents are able to apply either of the following classes of single-species allometric function to estimate the biomass in project trees. Refer to Method 10.2 on the allometric domain for further details.

(a) stratum-specific function: an allometric function developed by the proponent which has been developed from data collected exclusively from within a single stratum, the boundaries of which define the geographic limits of the allometric domain (Method 10.2).

(b) regional function: an allometric function developed by the proponent that is assumed to have an allometric domain that extends across a relatively large geographic area, potentially including multiple strata.

(c) CFI function: an allometric function developed and validated, and applied to a CFI project in compliance with a CFI determination, as demonstrated by an offsets report for which a certificate of entitlement has been issued under the Act.

Note A stratum-specific function can be applied outside of the stratum from which the allometric dataset was collected, however, where this occurs, the allometric function is to be treated as a regional function and must be validated using Method 14.

(4) In all cases, an allometric function may only be applied where the requirements detailed under this Method are met and the compatibility and validation tests described at Method 13 are applied in accordance with the requirements of the Determination.

10.2 Allometric domain

(1) An allometric function can only be applied to project trees that occur within the allometric domain for that allometric function.

(2) For any allometric function applied under the Determination, the proponent must clearly define and document, within an allometric report (Method 10.5), the allometric domain that relates to the allometric function. An allometric domain needs to be defined, at a minimum, by describing the following elements:

(a) The tree type from which the dataset used to develop the allometric function (referred to here as the allometric dataset) has been collected.

(b) the species of tree (noting this Technical Reference Guide describes development of single-species allometric functions);

(c) The explanatory variables for the allometric function;

(d) the smallest and largest value for each explanatory variable included within the allometric dataset (also referred to here as the allometric data range)

(e) Procedures used to measure explanatory variables (e.g. diameter at breast height (DBH) measured using diameter tapers or callipers); and

(f) The geographic area over which the allometric function is assumed to apply. In the case of a stratum-specific function, the bounds of the stratum from which the allometric dataset was collected defines the geographic limits of the allometric domain.

(3) To prevent introducing error and bias into carbon stock estimation, the procedures used to measure trees within plots during a carbon inventory must replicate the procedures used to measures biomass sample trees when developing the applicable allometric function.

(4) It is not permitted to use an allometric function if information is not available to satisfy the above requirements.

10.3 Fitting allometric functions using regression

(1) Allometric functions may only be applied where they have been derived using regression analyses.

Note Basic concepts and approaches are detailed in Snowdon *et al.* (2002), while Ryan (1997) and Seber & Lee (2003) provide further detail on the underlying statistical theory, concepts and techniques relating to performing regression analyses.

(2) Where a single explanatory variable is used (e.g. stem diameter), linear, or non-linear regression techniques can be applied.

(3) Where multiple explanatory variables are used (e.g. tree height and stem diameter), multiple linear, or non-linear regression techniques can be applied to develop a multivariate allometric function.

(4) In both cases (2) and (3), data must not be transformed (i.e. apply actual values) and the weighted least squares method must be applied to estimate the line of best fit.

Note for example applications of weighted least squares see: Clutter *et al*. 1983; Carroll & Ruppert 1988; Seber & Lee 2003; NIST/SEMATECH 2012.

(5) A weighting factor in the form of Equation 7.8 must be calculated to achieve constant variance (homoscedasticity) and the best fit for the regression.

Note Appropriate measures of best fit are discussed by Parresol 1999. They include the Fit Index and the Furnivall Index (Furnivall, 1961).

(6) Where stem diameter (D) or stem diameter equivalent (D_e) of multi-stem trees has been assessed, the appropriate weighting factor may be $1/D^2$ or $1/D_e^2$. Otherwise the appropriate weighting factor may be $1/D^{b1}$ where b_1 is a parameter to be estimated.

Note This is because the variance of biomass is commonly proportional to D^2 (or D_e^2) (Snowdon *et al* 2002). Ritson and Sochacki (2003) calculated b_1 values in the range 0.8 – 2.5 for allometric functions for total tree biomass and biomass of components of *Pinus pinaster* in farm forestry plantations in Western Australia. Clutter *et al*. 1983 (pp 24 – 27) suggest other weighting factors where stem diameter and tree height has been measured for volume and biomass prediction models (allometric functions). If Crown Volume Index (CVI, Ritson *et al*. 1991) has been measured the appropriate weighting factor will be $1/CVI^{b1}$.

(7) allometric functions must be of the form:

$$y = f(x_1, x_2, \dots x_n)$$

for example, the following:

$$y = b_1 x_1^{b_2}$$

$$y = b_0 + b_1 x_1^{b_2}$$

$$y = b_0 + b_1 x_1^{b_2} x_2^{b_3}$$

$$y = b_0 + b_1 x_1^{b_2} x_2^{b_3} + b_4 x_3^{b_5}$$

where:

y	Response variable, e.g. total tree biomass, above-ground biomass.
$x_1, x_2, \dots x_n$	Explanatory variables, e.g. stem diameter, tree height, crown dimensions.
$b_0, b_1, \dots b_5$	Parameters to be estimated by regression analysis.

10.4 Minimum data requirements

(1) An allometric function can only be applied under this Determination where the allometric function is fitted using regression analyses and data collected from at least 20 individual biomass sample trees sampled from within the geographic limits of the allometric domain (see Snowdon *et al.* 2002; AR-AM0011).

(2) All biomass sample trees must be live and unburnt and both above-ground biomass and root biomass components must be estimated.

(3) Root biomass may be estimated by a root:shoot ratio or by destructive sampling.

10.5 Minimum regression fit requirements

(1) For an allometric function to be considered acceptable for estimating biomass within a given allometric domain, the following conditions must be met.

(2) The regression relationship upon which the allometric function is based must be statistically-significant (probability level of <0.05).

(3) The following statistical tests must be performed on actual (not weighted) data for the biomass sample trees to:

(a) Show that the allometric function is unlikely to overestimate tree biomass (above-ground biomass or total tree biomass in live and unburnt trees). i.e. the mean of the residuals (measured – predicted) is not significantly less than zero ($p < 0.05$ from a one-tailed, one-sample, t-test). Calculate the mean of residuals from Equation 7.7.

(b) Show there is no significant trend in the plot of residuals. A trend is significant if a significant ($p < 0.05$) linear or non-linear regression can be fitted to the plot of residuals.

(4) Where these conditions are not met, the proponent can apply any of the following processes.

(a) Refine the allometric domain so as to reduce variability, or alleviate bias. For example, this can include separating the allometric dataset on the basis of geographic location, size, sub-species, or growing conditions and then applying regression analyses to data sub-sets (resulting in a more narrowly defined allometric domains), noting that the minimum data requirements prescribed at Method 10.1 must still be met.

(i) The rationale for refining the allometric domain, including any selection of data sub-sets, must be documented and the proponent must be able to demonstrate that data points have not been subjectively removed from the dataset in order to reduce variability.

(b) Use multiple-regression techniques, including multiple explanatory variables, to explain more of the variability and alleviate bias (i.e. develop a multivariate allometric function).

(c) Conduct further sampling as per Methods 11.2 and 11.3, combine these data with the original dataset, and re-perform the regression analyses with reference to the combined allometric dataset.

(5) Outcomes of checks against the conditions in steps 3(a) and (b) must be documented in an allometric report and, wherever the approaches at 4(a) to (c) are applied, these must also be documented.

Method 11 Developing allometric functions for project trees

11.1 Introduction

(1) This Method describes the process for developing stratum-specific functions, updating stratum-specific functions, and developing and updating regional functions for predicting above-ground biomass or total tree biomass in live and unburnt trees. Refer to Method 12 for further information on processes specific to dead or burnt trees.

11.2 Developing and updating stratum-specific functions

(1) A stratum-specific function is developed as part of a carbon inventory, where TSPs have been established and assessed as per the processes described at Methods 5 and 8.

(2) The following steps describe the process for selecting and assessing biomass sample trees (BSTs) from within TSPs for the tree type of interest:

   (a) Divide all project trees occurring within the TSPs, into a minimum of five size classes based on measures of explanatory variables.

   (b) Then select an equal number of project trees from within each size class so as to achieve a minimum selection of 20 biomass sample trees.

(3) The following selection procedure must be followed:

   (a) Rank the project trees within a size class from largest to smallest.

   (b) Select the BSTs by evenly-distributed percentiles for size.

   (c) Calculate the percentiles from the series:

$$1\,\frac{50}{n}\,,\quad 3\,\frac{50}{n}\,,\quad 5\,\frac{50}{n}\,,\quad \dots\,,\quad (2n-1)\,\frac{50}{n}$$

   where n is the number of BSTs to select from a size class.

   (d) For example, Table 3 shows the percentiles where the number of BSTs varies from 1 to 6.

Table 3. Selection of BSTs from a size class. Select trees closest to the percentiles for size.

Number of BSTs	Percentiles.
1	50.0
2	25.0, 75.0
3	16.7, 50.0, 83.3
4	12.5, 37.5, 62.5, 87.5
5	10.0, 30.0, 50.0, 70.0, 90.0
6	8.3, 25.0, 41.7, 58.3, 75.0, 91.7

(e) If the required number of BSTs is not available in a size class, then attempt to take the shortfall from the next size class.

Note For example, suppose the objective is to select 4 BSTs from each of 5 size classes, and there are only 2 trees in the first (largest) size class. In this case, attempt to take an extra 2 BSTs (total 6 BSTs) from the next size class.

(4) Assess all biomass sample trees selected at step (2) using Method 11.5 and, if applicable, Method 11.6.

(5) Fit allometric functions using regression analysis as per the requirements of Method 10.3 and Method 10.5.

11.3 Updating stratum-specific functions

(1) It is likely that project trees will grow to a size beyond the allometric data range for a stratum-specific function from reporting period to reporting period. For this reason, this Method allows for a pre-existing stratum-specific function to be updated as follows.

(2) It is a pre-condition of applying this Method that a stratum-specific function has been previously developed according to Method 11.1 and that this Method 11.2 is applied as part of a carbon inventory.

(3) Where the conditions at Step 1 are met, apply Steps 1-3 of Method 11.1 with selection of a minimum of 10 biomass sample trees (instead of the 20 specified under Method 11.1).

(4) Combine the data collected from biomass sample trees at Step 2 with the allometric dataset used to develop the original stratum-specific function and then apply the process described at Step 3 of Method 11.1 to derive an updated regression function based on the combined allometric dataset.

(5) Where the conditions in steps 3(a) and (b) at Method 10.5 are met, the updated stratum-specific function can be applied within the stratum from which the allometric dataset was derived without applying the validation process described at Steps 6 and 7 of Method 13.

(6) Where the conditions in steps 3(a) and (b) at Method 10.5 are not met, the proponent can restrict the dataset to the biomass sample trees assessed at Step 2 and apply Method 11.1 to develop a new stratum-specific function, ensuring that a minimum of 20 biomass sample trees are assessed.

(7) Details of biomass sample tree selections must be documented as per Method 11.1.

11.4 Developing and updating regional functions

Developing regional functions

(1) A regional function can be developed at any time (i.e. does not require linkage to a carbon inventory) from trees that occur within, or outside of, the project area. The process for developing a regional function is described in the following Steps.

(2) Define the allometric domain of interest (Method 10), including its geographic limits.

(3) From within the geographic limits of the allometric domain, map the sites (referred to as biomass sample sites) that are available for assessment of biomass sample trees for the tree type to be referenced by the regional function.

(4) From within the biomass sample sites, randomly select a minimum of 5 locations for the establishment of biomass sample plots (Step 4).

    (a) Locations for biomass sample plots (BSPs) must be established using the process described at Steps 1-5 of Method 7, replacing all references to ‘stratum’ with ‘biomass sample plots’ (or BSP), ignoring all references to probable limits of error requirements and replacing the term ‘plot’ with ‘biomass sample plot’ (or BSP).

(5) For each location selected at Step 3, establish BSPs as per Steps 5-8 and 10-14 of Method 8, replacing the term ’plot’ with ‘biomass sample plot’ (or BSP) ignoring references to minimum plot size and instead setting minimum plot size at 100 m^2 (0.01 ha).

    (a) The proponent must ensure that the combination of plot size and number of BSPs allows for a minimum of 100 trees of the tree type to be referenced by the regional function to be included within the BSPs.

(6) Rectangular BSPs (including belt plots) must have the centre, or the centre line, temporarily marked. Circular BSPs must have the centre temporarily marked. In both cases, markers should allow for a return visit within 12 months of assessment.

(7) From within the BSPs, identify all occurrences of the tree type to be referenced by the regional function and measure candidate explanatory variables from each of these trees.

(8) Select a set of at least 20 biomass sample trees as per Steps 1 of Method 11.1, replacing the term 'temporary sample plot'(TSP) with BSPs and replacing the term 'project trees' with 'trees'.

(9) Assess all biomass sample trees selected at Steps 1 and 2 using the process described at Method 11.4, then fit a regression function and analyse as per the requirements of Method 10.

Updating a regional function

(10) To update a regional function, re-assess the original BSPs or, if they are no longer available (e.g. if they have been clearfelled), establish new BSPs. Then, at a minimum, select trees from each size class unrepresented by the existing data range, so that the number of trees within each size class is consistent, and selected and analysed in a manner consistent with steps (1) to (9).

11.5 Measuring above-ground biomass of biomass sample trees

(1) A project proponent must undertake the processes specified in this method when assessing the above-ground biomass of a biomass sample tree.

(2) For each biomass sample tree, measures of candidate explanatory variables must be collected.

(3) The biomass sample tree must be cut at ground level and the above-ground material separated into biomass components.

(4) As a minimum, the components specified in step (3) must include:

- (a) stem;
- (b) crown (branches and foliage); and
- (c) dead material, including dead branches, dead stem and dead foliage, attached to the biomass sample tree.

(5) After completing step (3), the total wet-weight for each of the above-ground biomass components must be recorded and documented in an allometric report.

(6) For each biomass sample tree a representative sub-sample must be collected from each biomass component and weighed immediately after carrying out step (5) to obtain the sub-sample wet-weight.

(7) The wet-weight of the sub-samples from step (6) must be recorded and documented in an allometric report.

(8) The following must be oven-dried to constant weight at 70 degrees Celsius to obtain the dry-weight:

- (a) the sub-samples specified in Step (6), or
- (b) the biomass component specified in Step (12).

(9) The following must be recorded and documented in an allometric report:

   (a) the dry-weight of the sub-samples that have been oven-dried in accordance with Step (8); or

   (b) the biomass component specified in step (12).

(10) The dry-wet weight ratio for each of the sub-samples specified in Step (6), or the biomass component as specified in Step (12), must be calculated by dividing dry-weight by wet-weight.

(11) The dry-weight of each above-ground biomass component of the biomass sample tree must be estimated using Equation 7.6 in the Determination and applying the average of the dry-wet weight ratios from Step (10).

(12) As an alternative to the sub-samples specified in Step (6), the entire biomass component may be used in the processes specified in Steps (7) to (11).

11.6 Measuring root biomass of biomass sample trees

(1) Project proponents may apply a root:shoot ratio to estimate root biomass of project trees from above-ground biomass (Method 11.5). In this case, the allometric function for the tree species must predict above-ground biomass only.

(2) Alternatively, a project proponent may sample roots directly to develop allometric functions to predict total tree biomass. In this case the following procedures in Steps (3) to (14) apply.

(3) The roots of each individual biomass sample tree that will be sampled and measured must be excavated.

(4) Roots that have a diameter of less than 2 millimetres must not be included in the processes specified in Steps (6) to (13), except where the roots are attached to larger root sections.

(5) The excavated root system must be cleaned so that contamination from soil and any other contaminants is minimised.

(6) Once excavated and cleaned, the root system must be divided into its separate biomass components which must include at least:

   (a) the tap root or lignotuber***;*** and

   (b) the lateral roots.

(7) After completing the processes specified in Step (6), the total wet-weight for each of the separated below-ground biomass components must be recorded and documented in an allometric report.

(8) For each biomass sample tree representative sub-samples must be collected from each biomass component and weighed immediately after carrying out the requirement specified in step (6) to obtain the wet-weight.

(9) The wet-weight of all sub-samples specified in step (8) must be recorded and documented in an allometric report.

(10) The following must be oven-dried to constant weight at 70 degree Celsius:

(a) the sub-samples specified in step (8); or

(b) the biomass component as specified in step (14).

(11) The following must be recorded and documented in an allometric report:

(a) the dry-weight of the sub-samples that have been oven-dried in accordance with step (10); or

(b) the dry-weight of the biomass component as specified in step (14).

(12) The dry-wet weight ratio for each of the sub-samples specified in step (8), or the biomass component as specified in step (14), must be calculated by dividing dry-weight by wet-weight.

(13) The dry-weight of each below-ground biomass component of the biomass sample tree must be estimated using Equation 7.6 and applying the dry-wet weight ratios as specified in step (12).

(14) As an alternative to the sub-samples specified in step (8), the entire biomass component may be used in the processes specified in steps (9) to (13).

11.7 Estimating root biomass with a root:shoot ratio

(1) The alternative method to direct sampling of roots provided in Method 12.6, is to:

(a) calculate an allometric function to predict above-ground biomass of project trees and test trees; and

(b) then apply a root:shoot ratio to estimate the root biomass of those trees.

Note The root:shoot ratio is the ratio of below-ground biomass (roots) to above-ground biomass (shoots).

(2) The process to obtain estimates of the root:shoot ratios used in the National Inventory Report is as follows:

(a) Using the publically-available version of FullCAM and following the FullCAM Guidelines specific to this Method:

(i) Select a central point in a modelling stratum for any simulations for that stratum; and

(ii) Select the tree species (individual species or species group) that best describes the stratum and run a simulation.

(3) Calculate the root:shoot ratio for the relevant tree age as the ratio of “C -mass of below ground tree components” to “C-mass of above ground tree components”.

Note Under this Method 12.7, all trees in a modelling stratum will have the same root:shoot ratio.

(4) Root biomass is then calculated as the product of predicted above-ground biomass (Equation 7.1) and the root:shoot ratio (Equation 7.5).

Note The above Steps (1) – (4) only apply to estimating root biomass of un-harvested trees. For assessing the biomass in roots of harvested trees see Method 11.8 below. Equation 7.3 is, in effect, an allometric function. An allometric function relates the growth of one part of an organism to the whole or another part of an organism. In Equation 7.5, the growths of the roots of a tree are related to the growth of the shoots.

11.8 Assessing carbon stocks in the roots of harvested trees

(1) Accounting for carbon stocks in the roots of harvested trees is optional.

(2) Under the Determination all forests must be re-established after clearfell harvesting. This may be by planting or seeding (replant systems). Alternatively, the forest may regenerate from the growth of new shoots (coppice) arising from the stumps or lignotuber/root crown of harvested trees (coppice systems).

(3) An essential difference between replant and coppice systems is that only in coppice systems do the roots remain alive after harvest. Therefore different methods are required for replant and coppice systems for estimating the root biomass after harvest.

Replant Systems

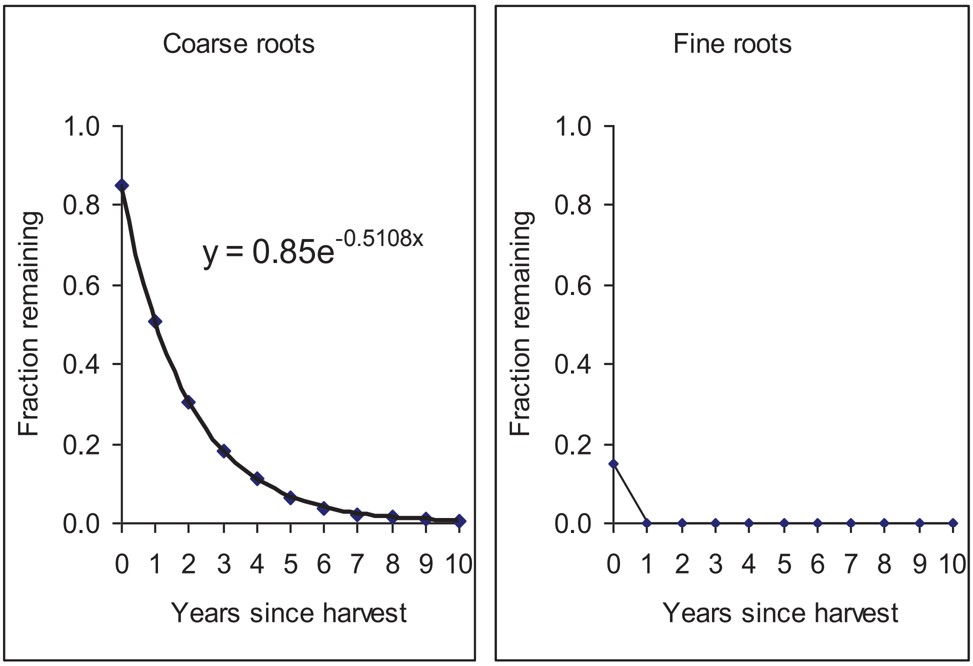
(4) The procedure for estimating the carbon stocks in the roots of harvested trees in the FullCAM Guidelines may be used.

(5) Otherwise, the default dead root partitioning and decomposition rates from the National Inventory must be used as indicated in Table 4.

(6) Table 4. Decomposition rates for roots of harvested trees in 'post-1990 plantations'.

Component	Breakdown rate / year
Coarse dead roots	0.4
Fine dead roots	1.0

(7) From DCCEE (2011, Tables 7.B4 & 7.F7) a typical fine root fraction in roots immediately post-harvest was estimated to be 0.15. Therefore, the model of root decay after harvest is shown in Figure 8 and Equation 4.11.

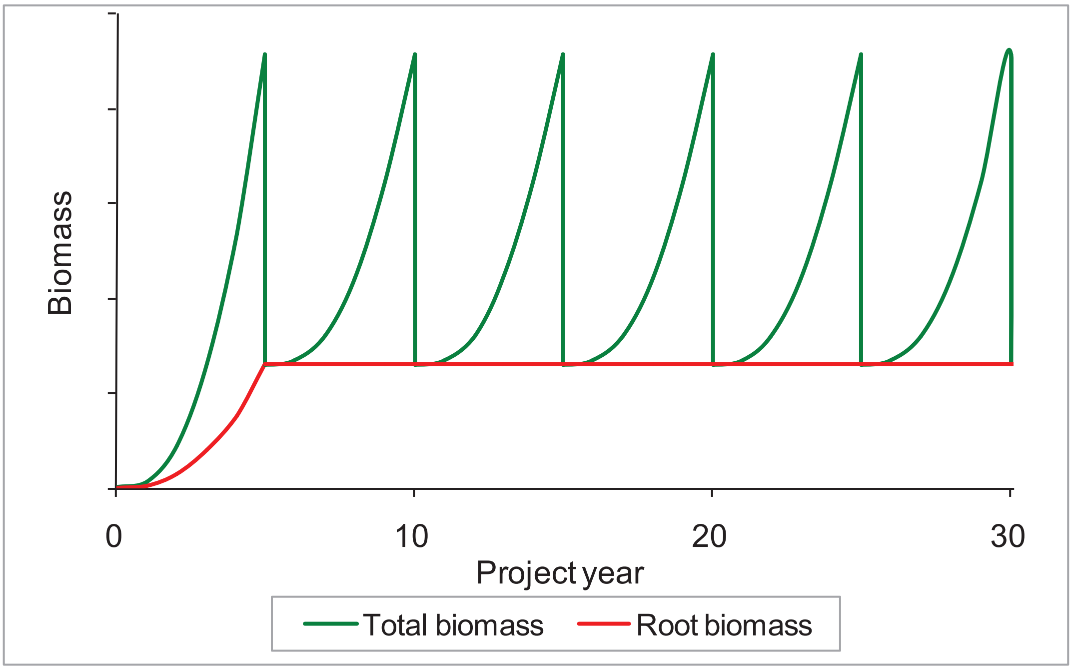


(8) Figure 8. Coarse and fine root decay (breakdown rate) in the first 10 years after harvest.

Coppice Systems

(9) For coppice systems, a simple conservative model for predicting root biomass after harvest in reforestation managed on a coppice system is applied as per step (10).

(10) For the purpose of estimating root biomass, it is assumed all tree roots remain alive after harvest, but do not change in biomass after the first harvest (Figure 9 and Equation 4.12).



(11) Figure 9. Example of projected biomass from a 5-year harvest cycle and coppice regeneration. Root biomass is assumed to remain constant from the time of the first harvest.

11.9 Record-keeping and reporting

(1) Proponents must retain records of all measures collected and their quality assurance, identifying:

- (a) the type of equipment used to collect measures;
- (b) the calibration of equipment ; and
- (c) the error checks that were applied throughout measurement.

(2) To demonstrate that field crews were correctly applied the methods used, proponents must keep the following records:

- (a) training of field crews;
- (b) records demonstrating all measurement equipment was regularly checked for measurement error: and
- (c) records demonstrating the corrective action applied where measurement error was identified.

(3) Proponents must retain records that demonstrate constant dry weight is achieved:

- (a) for method 11.5—at step 8,
- (b) and if applicable, for Method 11.6— at step 10.

(4) Details of the approach to selecting biomass sample trees must be documented in a sampling plan (Method 6).

(5) Details of:

(a) the approach to measuring biomass sample trees,

(b) regression analyses at Method 10.3,

(c) the outcomes of the minimum fit tests described at Method 10.5 step (3); and

(d) the outcomes of Method 10.5(4) if applicable.

must be documented in an allometric report which meets the requirements specified in the Determination.

(6) Errors, including their sources, magnitude and likely influence on biomass estimates, also need to be detailed in an allometric report which meets the requirements specified in the Determination.

Method 12 Accounting for dead or burnt trees.

12.1 Biomass prediction

(1) Accounting for carbon stocks in dead and burnt trees is optional.

Note A burnt tree is a tree that has lost biomass in a fire.

(2) To account for carbon in dead or burnt project trees, apply the procedures at steps (3) to (7).

(3) Measure the explanatory variables.

Note For example, if above-ground biomass (AGB) of a tree is predicted from a stem diameter measurement such as Diameter at Breast Height (DBH), measure DBH.

(4) For each component of above-ground biomass (AGB) of the tree, estimate the fraction remaining (F_R) . This must be a number greater than 0 and less than or equal to 1.

Note For example F_R = 0.65 indicates that the biomass is 65% of what would be there if the tree was not dead or burnt and had the same DBH (or other predictor measures).

(5) The fraction remaining must not exceed the limits in Table 5. If it does exceed the limits there is a procedure in Method 12.2 to reduce the maximum fraction remaining values.

(6) Table 5 - Maximum fraction remaining values that may be recorded in field assessments of dead or burnt trees.

Foliage	Branches	Bark	Stem	Maximum fraction remaining (F_R)
y	y	y	y	0.9
x	y	y	y	0.7
x	x	y	y	0.5
x	y	x	y	0.5
x	x	x	y	0.3
x	x	x	x	0.1

Where:

- A “y” in the table indicates the biomass loss of the component is less than or equal to 10%. i.e. the component is substantially intact despite the tree dying or being burnt.
- An “x” in the table indicates the biomass loss of the component is greater than 10%. i.e. > 10% biomass or more has been lost as the result of the tree dying or being burnt.
- Foliage: leaves or equivalent material, e.g. phyllodes
- Branches: woody material, not stem
- Bark: bark (phloem) material on stems.

- Stem: a dominant or co-dominant lead shoot.

(7) Calculate the AGB of any dead or burnt trees from Equation 7.2 of the Determination.

(8) If root biomass is estimated using the root:shoot ratio as per method 11.7 and Equation 7.5 assume the same ratio for root to (measured) above-ground biomass as applies to live and unburnt trees.

12.2 Testing for over prediction of a dead or burnt tree biomass

(1) If ≥ 5% of tree biomass in a stratum is in dead or burnt trees a similar t-test to that applied to allometric functions developed on live and unburnt trees (Method 10.4) must be applied to the allometric function for the dead or burnt tree using the process in steps (2) to (6) as follows:

(2) Select ≥ 20 dead or burnt trees from TSPs in the stratum, using the process described at Step 1 of Method 11.1, replacing references to 'biomass sample trees' with 'dead or burnt sample trees'.

(3) Record the measure(s) of explanatory variables and fraction remaining (F_R) of the dead or burnt sample trees, applying the maximum fraction remaining values from Table 5. Calculate predicted biomass from Equation 7.2.

(4) Assess the biomass of the dead or burnt sample trees directly through destructive sampling (Method 11.4).

(5) Apply the same t-test as described at Step (3)(a) of Method 10.5.

(6) Where the result of the t-test indicates the allometric function over-predicts the proponent must adjust the maximum fraction remaining values for all cases in Table 5 proportionately so that the mean of residuals (measured – predicted) is not less than zero.

(7) The adjusted maximum fraction remaining values must then be applied in all calculations of project carbon stocks for that stratum.

Method 13 Applicability of allometric functions

13.1 Testing the applicability of allometric functions

(1) An allometric function can only be applied to estimate biomass for project trees that fall within the domain of that allometric function.

(2) The proponent is required to check compatibility on each occasion that an allometric function is to be applied to project trees within a stratum, the outcomes of checks must be documented within an offsets report.

(3) Confirm that measures of explanatory variables collected during the carbon inventory do not exceed the allometric data range by more than the following limits:

(a) up to 5% of project trees can exceed the largest predictor measure by up to 20%; and

(b) up to 10% of project trees can be smaller than the smallest predictor measure.

(4) Confirm that the species is the same as those referenced by the allometric function.

(5) Confirm that field measurement of values for explanatory variables during the carbon inventory used the same measurement procedures as for development of the allometric dataset.

(6) Where a stratum-specific function is to be applied, confirm that it is being applied to the relevant stratum.

13.2 Validation test

(1) Subject to step (2), the proponent is required to perform the validation test at the following times:

(a) during the first reporting period that a regional function or CFI function is to be applied within a stratum; and

(b) during the last reporting period for the crediting period.

(2) The validation test must be performed as part of a carbon inventory and be documented in an offsets report.

(3) The validation test is as follows:

(a) divide all project trees occurring within the TSPs into at least five size classes based on measures of the explanatory variables.

(b) then select an equal number of project trees from within each size class so as to achieve a minimum selection of 10 biomass sample trees (BSTs) using the process at Step 2(c). To select BSTs from within size classes undertake the following:

(i) apply the process described at Steps (1) to (4) of Method 11.2.

(i) where there is only a total of 10 project trees of the relevant tree type represented within the TSPs, it is acceptable to select all of these as test trees (i.e. without applying the selection process).

(b) Where less than 10 project trees of the relevant tree type occur within the TSPs, the proponent must either:

(i) establish further TSPs (as per Method 5) until the tree type is sufficiently represented to allow this Step; or

(ii) assume carbon stocks for that tree type are zero on all occasions that it is included within a TSP or PSP. If this option is applied it is not necessary to conduct the further validation Steps in this Method.

(c) assess each test tree according to Methods 11 and 12.

(d) using the allometric function and measures of explanatory variables collected from the test trees, predict the biomass contained within each of the test trees.

(e) using the measured and predicted biomass estimates generated at steps (3)(c) and (d) respectively apply the same statistical tests as outlined in Method 10.5 step (3) to show:

(i) the allometric function is unlikely to overestimate tree biomass; and

(ii) there is no significant trend in the plot of residuals.

(5) The above validation test is applicable to allometric functions for live and unburnt trees. However, if ≥ 5% of tree biomass in a stratum comprises dead or burnt trees a separate validation test must be applied to dead or burnt trees for that stratum.

(6) Outcomes of all compatibility and validation tests described under this Method are to be detailed in the offsets report, including any substitution, or development of stratum-specific allometric functions arising as a result of these tests.

Method 14 Assessing carbon stocks in coarse woody debris (CWD)

14.1 Introduction

(1) The measurement of coarse woody debris (CWD) is optional.

(2) CWD is typically fallen (naturally or as a result of pruning and harvesting) branches and stem parts . For this methodology CWD is defined as fallen tree material with a diameter (or thickness) > 25 mm. CWD does not include dead roots.

(3) As CWD may have decayed or decomposed, this has to be taken into account when assessing carbon stocks in CWD.

(4) If CWD is to be included in an assessment, the Line Intersect method must be used.

> ***Note*** For further information on the line intersect method see (Bell *et al*., 1996; O'Hehir and Leech, 1997; Ringvall and Stahl, 1999; van Wagner and Wilson, 1976; Warren and Olsen, 1964).

(5) Polygon transects should be used for block plantings (Figure 10) and zig-zag transects for belt plantings (Figure 11).

(6) The plot (TSP or PSP) centres are used to define the centres of the transects.

(7) The total length of transect at any sample plot must be ≥ 40 m.

14.2 CWD estimation – common features of transects

(1) Procedures which are common for either shaped transect (depicted in Figure 10 and 11) are provided in Steps 2 to 12 as follows:

(2) The "pegs" indicated in Figure 10 and Figure 11 can be either temporary pegs or permanent (e.g. survey marks) if the intention is to re-measure CWD on the same transects in later assessments.

(3) A tape measure can be laid out around the pegs and along the transect for recording distances.

(4) Record the diameter (mm) of any debris > 25 mm diameter that intersects the transect (tape measure). Diameters should be measured perpendicular to the long axis of any piece of debris.

(5) Record the decay class at each diameter measurement. See notes on decay classes below.

(6) For each stratum in the assessment, take ≥ 2 samples from each decay class to estimate density (method below). Measure the length and diameter of each sample.

(7) If an edge plot, apply the mirage method (Method 9.2).

(8) Consistent criteria for determining decay classes should be applied. As a guide, the following classes could be defined:

(a) Class 1. Bark still attached.

(b) Class 2. Bark off, no fragmentation apparent.

(c) Class 3. Fragmentation commenced, but the piece can be picked up without it crumbling.

(d) Class 4. The piece crumbles if it is picked up (advanced fragmentation).

Note Often, there will only be one or two decay classes in a stratum, e.g. all Class 1, or all Class 1 and Class 2.

Estimating density of decay class samples:

(9) Measure the volume of samples by either:

(a) Water displacement - one suitable method involves inserting a fine skewer into a sample so it can be immersed in a beaker of water. If the beaker is placed on a balance, the weight increase in grams equals the sample volume in cm^3. If the sample is porous or has cavities, wrap the sample in thin plastic (e.g. cling wrap) before immersion; or

(b) Measurements – take sufficient measurements (diameters and length) to estimate the volume, and apply Smalian's formulae for log volume.

Note Smalian's formulae for log volume is described in detail at: http://www.for.gov.bc.ca/ftp/hva/external/!publish/web/manuals/scaling/chapters/Ch4.pdf

(10) All samples should be dried to constant weight in a fan-forced oven at a temperature of 70 degrees Celsius to determine the dry-weight.

(11) Density is calculated as the dry-weight divided by the volume.

(12) Calculate the estimate of carbon stocks within a plot from Equations 4.6, 4.7 and 4.8.

14.3 CWD estimation in block plantings

(1) Polygon transects should be established in block plantings as follows:

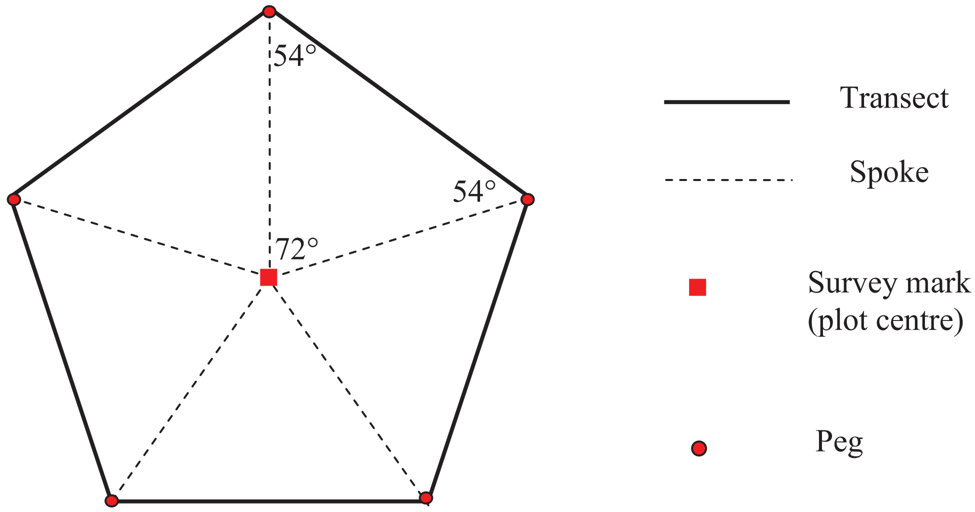
(2) The polygons should be regular with an uneven number of sides, e.g. 3, 5, 7, or 9 sides. These shapes are less prone to bias due to the orientation of the debris than an "L" or "square" shape (O'Hehir and Leech, 1997). Figure 10 shows a 5-sided (pentagon) layout.

(3) For each sample plot randomly select the orientation for one spoke in the range 0° - 359° relative to true north. .

(4) The length of the spokes must be selected to give a transect with the minimum 40 m total length.

Note For example, if spokes of a pentagon are 7.98 m (i.e. radius of a standard 0.02 ha circular plot), transect length = 46.9 m.

(5) Figure 10. Pentagonal transect for CWD and litter estimation.



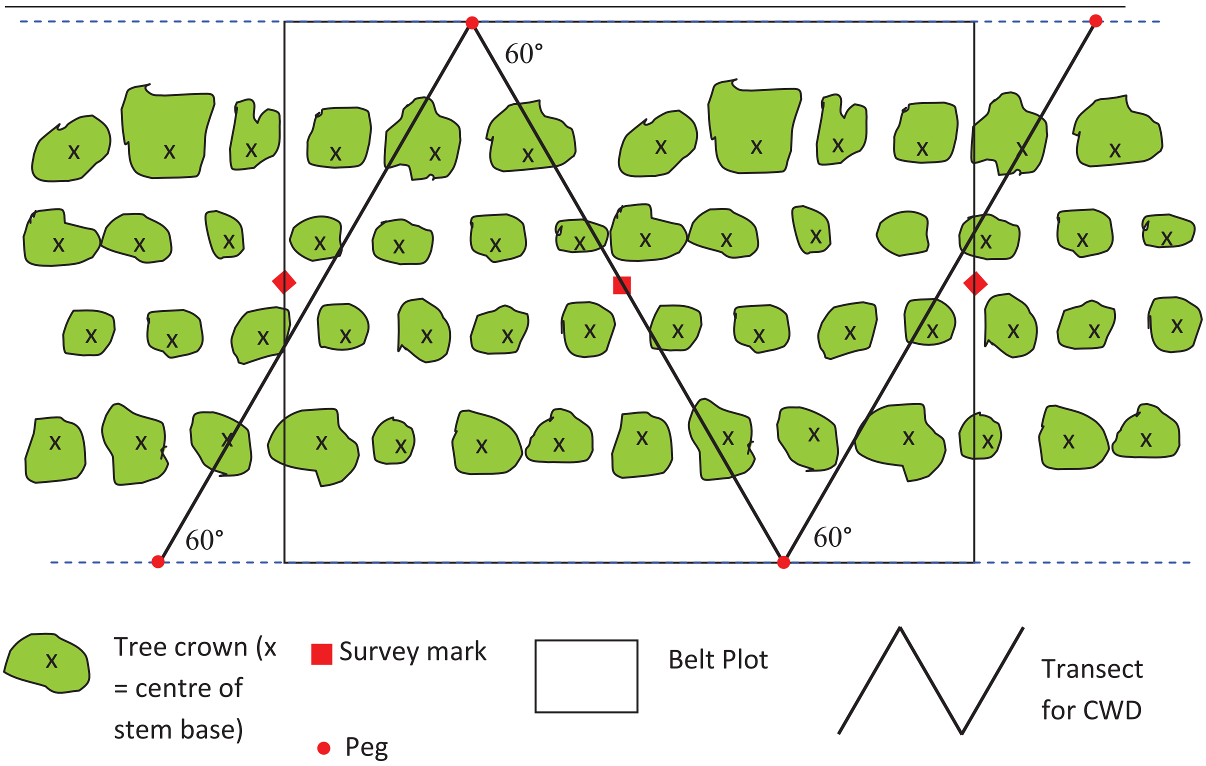
14.4 CWD estimation in belt plantings

(1) Zigzag transects should be established in belt plantings as follows:

(a) Lay out the transect as indicated in Figure 11.

Note If observed from outside the belt the segment of the transect passing through the plot centre slopes 'right to left' as shown in Figure 11.

(b) There should be an uneven number of segments in the transect, total ≥ 3, e.g. 3, 5, 7 … segments, such that the total length of the transect is ≥ 40 m.



(2) Figure 11. Example of a 60º zigzag transect for CWD and litter estimation.

Method 15 Assessing carbon stocks in litter

15.1 Introduction

(1) Accounting for carbon stocks in litter is optional.

(2) Litter is defined to be ‘fallen tree material with a diameter (thickness) ≤ 25 mm’. It will typically be mostly fallen leaves, twigs and small branches, but may include other material such as fallen bark and capsules (fruit).

(3) This approach is recommended where the litter layer is well defined and deep (> 50 mm depth).

15.2 Develop a litter prediction equation

(1) Develop a regression equation for the stratum that relates depth of litter to the mass per unit area using steps 1(a) to (c) as follows:

(a) Collect litter samples using litter sampling rings, e.g. standard 0.05 m^2 ring. The samples should include all litter to mineral soil.

(b) Measure litter depth to mineral soil using litter depth gauges.

Note As described by Sneeuwjagt and Peet (1985).

(c) Litter samples should be dried to constant weight in a fan-forced oven at a temperature of 70 degrees Celsius.

Field measurements

(2) Litter depth measurements should be sampled on the same line transects used for CWD assessments (Method 14), i.e. regular polygons with an uneven number of sides for block plantings and zig-zag transects for belt plantings.

(3) A minimum of 20 evenly-spaced depth measurements are required along any transect.

Note For example, as the minimum transect length is 40 m, measurements 2 m apart will give ≥ 20 measurements.

(4) Apply Equations 4.4 and 4.5 in the Determination to calculate carbon stock density in litter as the average from all measurements on a plot.

15.3 Developing and testing equations for litter prediction

(1) The functions for predicting litter mass from litter depth are allometric equations. Consequently, the requirements for developing (Method 10) and testing allometric (Method 13) functions must be applied with the modifications specified in step (2).

(2) Replace references to “trees” with references to “litter measurement points” as follows:

(a) Replace “biomass sample tree” with “litter sample point”;

(b) Relace “project tree” with “litter measurement point”;

(c) Replace “tree type” with “litter type”; and

(d) Replace “test tree” with “test litter point”.

(3) To develop a stratum-specific function:

(a) Calculate average litter depth of all TSPs in a carbon inventory.

(b) Rank the TSPs by average litter depth.

(c) Select the TSPs closest to the 10^{th}, 30^{th}, 50^{th}, 70^{th}, & 90^{th} percentiles for average litter depth. (Total 5 TSPs).

(d) At 10 even-spaced points along each of the 5 transects (total 50 points):

(i) Measure the litter depth;

(ii) Take a litter sample (e.g. 0.05 m^2 in a litter sampling ring) for oven drying; and

(iii) Calculate litter mass for each sample point in $t.ha^{-1}$.

(4) Otherwise apply the procedures in Method 10 for defining the allometric domain, and fitting regressions.

Updating a litter stratum-specific function

(5) To update a stratum-specific function the same procedures as in step (2) above apply, except select for sampling the TSPs closest to the 10^{th}, 50^{th}, & 90^{th} percentiles for average litter depth (for a total of 3 TSPs and 30 sample points).

Developing a regional function for litter

(6) To develop a regional function the same procedures as in step (2) above apply, except replace “TSP” with “biomass sample plots “BSPs”.

Testing a litter allometric function

(7) To test an allometric function (stratum-specific or regional function):

(a) Select 30 sample points for measurement of litter depth and litter mass, applying the same selection procedure as in step (3) above.

(b) Apply the procedures in Method 13 for compatibility checks and validation testing.

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