Survey protocol for Woodland Carbon Code projects
Draft version 3.0
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Contents

Introduction

This document sets out the survey protocol for most Woodland Carbon Code projects. There may be very large, small or hard-to-access projects where you should refer to the carbon assessment protocol for a more appropriate methodology. This protocol summarises a subset of methods from the carbon assessment protocol:

For this survey, trees are divided into three categories which are treated differently:

Tree size category	Definition
Seedling	A living stem less than 50 centimetres tall.
Sapling	A living stem 50 centimetres or more tall and with a dbh less than 7 centimetres.
Tree	A living stem with diameter at breast height of 7 centimetres or more.

Year 5 assessment: The purpose of this methodology is to confirm the stocking density and health of seedlings and saplings in Woodland Carbon Code projects at approximately five years after planting.

Year 15+ assessment: The purpose of the year 15+ methodology is to confirm the carbon stock of the tree biomass (seedling, sapling and tree) at a point in time, as well as tree health.

Year 10 assessments where required: In cases where a project is classified as 'red' status at the Year 5 verification and a year 10 assessment is required, this assessment should follow the year 5 'stocking density' methodology.

If projects choose to do a year 10 assessment as part of the Woodland Carbon Guarantee, the project developer can choose to use either

- The year 5 'stocking density' methodology if most stems are less than 7cm dbh or
- The year 15 'mensuration' -methodology if most stems are 7cm dbh or greater.

Survey work can be summarised in five easy steps, which are explained in further detail below:

1. **Stratify:** If necessary, divide your project area into sub-areas which are of similar makeup
2. **Plot size:** Decide how big your plots will be, based ~~up~~on planting density

3. **Plot number and location:** Decide how many plots you need, based ~~up~~on the area / sub-areas, and where they should be located
4. **Get your survey plan approved by your chosen verification body**
5. **Survey:** Go to the site and count/measure trees
6. **Calculate:** Enter data into spreadsheet to work out planting density (year 5) or carbon stock (year 15+) and overall tree health

You should carry our assessment during the growing season where possible to assess tree health more accurately.

The project developer should also submit a project progress report and other documents to your chosen verification body once you have completed your survey work. See guidance on preparing and submitting documents.

1. Stratify

1. Locate your Woodland Carbon Code project map from validation. Ensure that the gross project boundary, planted or regenerating areas, open ground and existing woodland are clearly mapped. See mapping rules.

2. If your validation map did not include open ground, you should map and identify open areas greater than 0.25ha as a separate sub-area. Where this is not possible and/or open ground is randomly placed throughout, for example in a native woodland planting scheme, a greater number of sample plots will be required (see 3. plot number and location).

3. Sub-divide the net planted area into relatively uniform strata. This can be based on planting year, species, growth rates or stocking density.
4. ~~Note that t~~The variation within a stratum should be less than the variation between strata. This means that you should divide the woodland into fairly uniform areas.
5. The stratification at year 5 could well differ from the stratification at year 15 or subsequent years.
6. See an example in Figure 1.

~~a. Species planted in an intimate mixture, or areas where spacing is variable should be considered as one stratum~~

a. Conifers and broadleaves should be kept separate unless planted in an intimate mixture
b. Natural regeneration should be a separate stratum
c. Species planted in an intimate mixture should be considered as one stratum.
d. Areas with variable planting density, for example native planting, should be considered as one stratum.
~~b.~~e. ~~Small A~~areas of similar planting density (i.e. densities within 500 stems/ha of each other) can be combined using the average spacing/ planting density calculator in the survey plan~~ning tab of the Monitoring Report~~. For example, you can combine areas planted at 1600 stems/ha and 1100 stems/ha but you can't combine areas planted at 1600 stems/ha with areas planted at 2500 stems/ha.
~~c.~~f. ~~At year 5, a~~Areas planted across a maximum of three planting seasons can be considered as one stratum

~~4. Natural regeneration should be a separate stratum~~

g. Any area up to two hectares and up to 5% of the site can be combined with the next most similar planting area

5.7. Decide whether the strata you have selected are ‘uniform’ or ‘variable.’ We do this because areas with greater variability require more plots to obtain a result of similar precision: A stratum would be considered uniform if trees were:

a. Planted within three years and were of similar height (i.e. no more than 4m height difference) AND
b. Single species AND
c. Planting positions were evenly distributed (not clumped) AND
d. (from year 15 onwards) dbh range is ‘normal’.

And a stratum would be considered ‘variable’ if there areExamples of reasons Aa stratum shcould be considered ‘variable’ if any of the above criteria are not metinclude.: Several species are planted in an intimate mixture OR
The spacing of the planting positions is not uniform but varies across the stratum OR
From Year 15 onwards, more than 3 years / 4 metres height difference across the stratum or the DBH range is unusually wide.

For example, nNative species planted in an intimate mixture would normallyshould be considered ‘variable’.

It should be noted that the variation within a stratum should be less than the variation between strata. Please refer to section 3 – stratification in the carbon assessment protocol for further clarification.

Figure 1: Map of Bluebell Woods showing stratification into three strata, with oak and mixed broadleaves combined. They are similar yield class, the same spacing and less than 5% of the net woodland creation area.

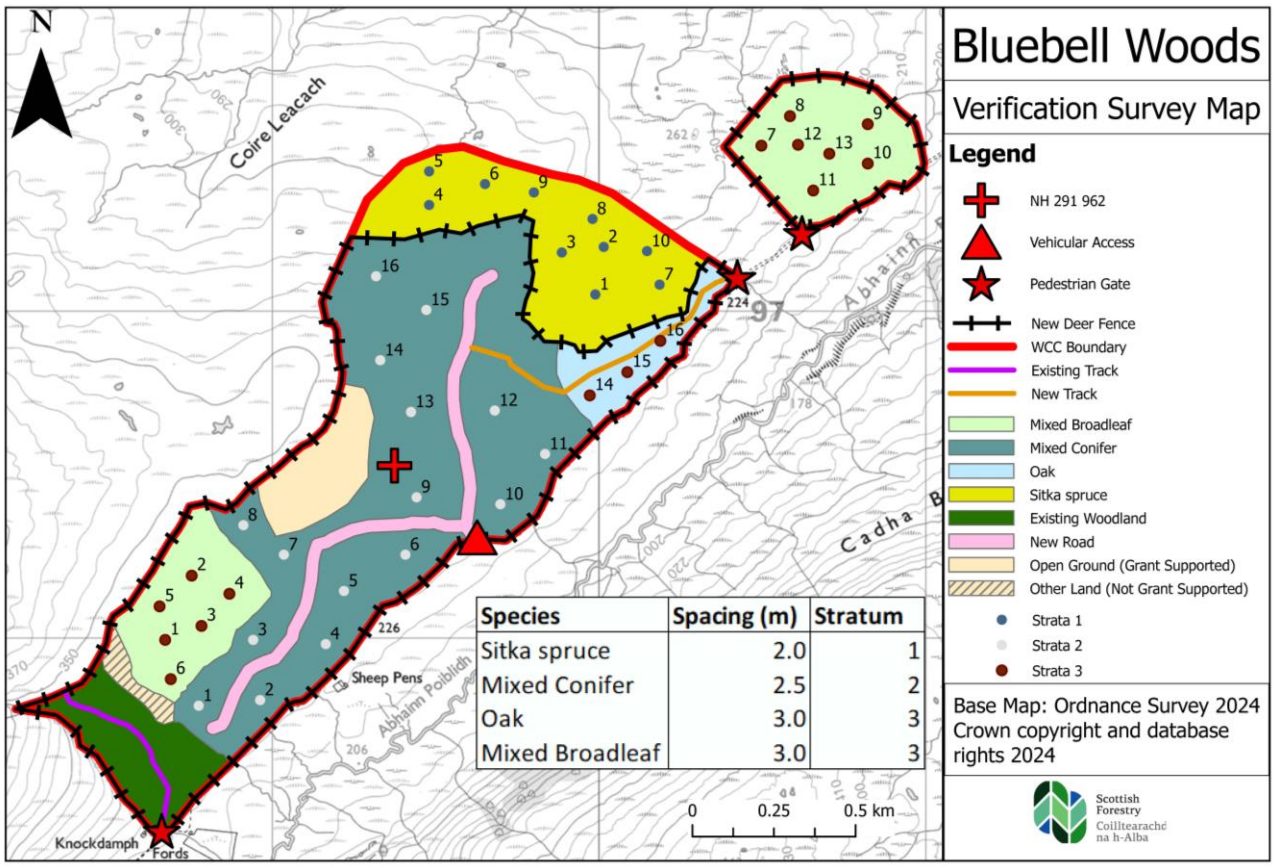

N
Coire Leacach
Sheep Pens
Knockdamph
Fords
Abhainn Poiblidh
Cadha
Abhainn
224
226
0 0.25 0.5 km
Species | Spacing (m) | Stratum
Sitka spruce | 2.0 | 1
Mixed Conifer | 2.5 | 2
Oak | 3.0 | 3
Mixed Broadleaf | 3.0 | 3
Bluebell Woods
Verification Survey Map
Legend
NH 291 962
Vehicular Access
Pedestrian Gate
New Deer Fence
WCC Boundary
Existing Track
New Track
Mixed Broadleaf
Mixed Conifer
Oak
Sitka spruce
Existing Woodland
New Road
Open Ground (Grant Supported)
Other Land (Not Grant Supported)
Strata 1
Strata 2
Strata 3
Base Map: Ordnance Survey 2024 Crown copyright and database rights 2024
Scottish Forestry
Coilltearachd na h-Alba

Table 1: Stratification of Bluebell Woods:

	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5	Total
Net area of each stratum (ha)	30.30	78.76	42.16			151.22
Open Ground/Existing woodland of each stratum (ha)				10.00		10.00
Gross area of each stratum	30.30	78.76	42.16	10.00	0.00	**161.22**
Uniform or Variable?	Uniform	Variable	Variable	Select one	Select one	
Species	Sitka spruce	Mixed conifers (Douglas fir and Larch)	Oak and mixed broadleaves			
Planned spacing (m)	2.0	2.5	3.0			
Planned stocking density (trees/ha)	2500	1600	1111			**Plot Shape**
Plot radius (m) if circular or length (m) if square.	5.6	8.0	8.0			Circular
Number of plots	10	16	16			

Further comments/ justification regarding your survey plan:

Oak and mixed broadleaves compartments are combined into one stratum as oak was planted at same density as mixed broadleaves and at 7.5 hectares is < 5% of the project's net area

2. Plot size and shape

1. Decide how big your plots should be for each stratum (see table 2). The aim is to have a plot size which includes at least
   a. At year 5: 20 live stems (seedling/sapling) or
   b. At year 15+: 7 to 20 trees greater than or equal to 7cm dbh
2. The number of plots depends on the spacing of each stratum. Table 2 shows the likely plot size for a range of planting densities/spacing.
3. The **plot size and shape should not vary across a stratum**. When you get to site, the surveyor should ensure that the plot size chosen for a stratum will pick up 20 stems for the majority of the plots. If in doubt or you think the stocking density could be less in other areas of the stratum, choose a larger plot size which will be suitable across the whole stratum.
   a. If your plot will not fit in your stratum boundary (e.g. your stratum is too thin for your plot) please contact the Woodland Carbon Code team for advice (info@woodlandcarboncode.org.uk).
4. You should ideally use circular plots as these are less likely to introduce bias. However, if you can clearly see the plant rows, you can use square plots. Plot shape should remain the same within a stratum/sub-area but can differ between strata/ sub-areas. For example, you could use a circular plot for a

native woodland stratum and a square plot for a regularly spaced Sitka spruce stratum.

4.5. Plot size and shape can vary between stratum if strata have different planting densities.

5.6. **If the ground to be surveyed is on a significant slope (e.g. over 25 degrees),** you may need to increase the plot size to account for the slope. Please see Annex 1 for advice on how to do this.

6.7. When measuring seedlings (at year 5 or year 15+), in situations where there is a relatively dense carpet of regeneration (greater than 5000 seedlings per hectare), the above method is likely to be unworkable due to the high number of seedlings that would be included in each plot. In such situations, reduce the plot radius to 4.0 metres (0.005 hectare) or 1.8 metres (0.001 hectare) so there is likely to be a minimum of 20 seedlings per plot. The seedling plot radius should remain the same for the whole stratum.

~~**If the ground to be surveyed is on a significant slope (e.g. over 25 degrees),** plot size may need to be increased to account for the slope. Please contact the WCC Secretariat for further advice before completing your survey (**info@woodlandcarboncode.org.uk**)Please see Annex 1 for advice on how to do this.~~

Table 2: Alternative plot size and area

Planting density (plants/ha)	Greater than or equal to 3967	2000 to 3966	1006 to 1999	399 to 1005	200 to 398
Spacing (m)	Less than or equal to 1.59	1.60 to 2.24	2.25 to 3.15	3.16 to 5.01	5.02 to 7.07
Plot area (ha) which gives at least 20 locations / plot	**0.005**	**0.01**	**0.02**	**0.05**	**0.10**
Circular plot radius (m) which gives at least 20 locations / plot	4.0	5.6	8.0	12.6	17.8
Square plot length (m) which gives at least 20 locations / plot	7.1	10.0	14.1	22.4	31.6

3. Plot number and location

1. Decide how many plots should be assessed based on:

   a. the area of the stratum
   b. the variability of the stratum (see table 3).
   c. The extent of open ground and whether it is mapped or not.

Table 3: The minimum number of sample plots for uniform and variable strata, based on the size of each stratum and whether open ground is clearly mapped.

Net area of stratum	Uniform stratum	Variable stratum – open ground mapped	Variable stratum – open ground is less than 20% and not mapped	Variable stratum – open ground is over 20% and not mapped
Less than 0.5ha	4	6	7	8
0.5 to 2.0ha	6	8	9	10
2.0 to 10.0ha	8	12	14	16
~~Over~~ 10.0 to 20ha	10	16	19	21
Over 20~~-30~~ ha	20	24	27	30

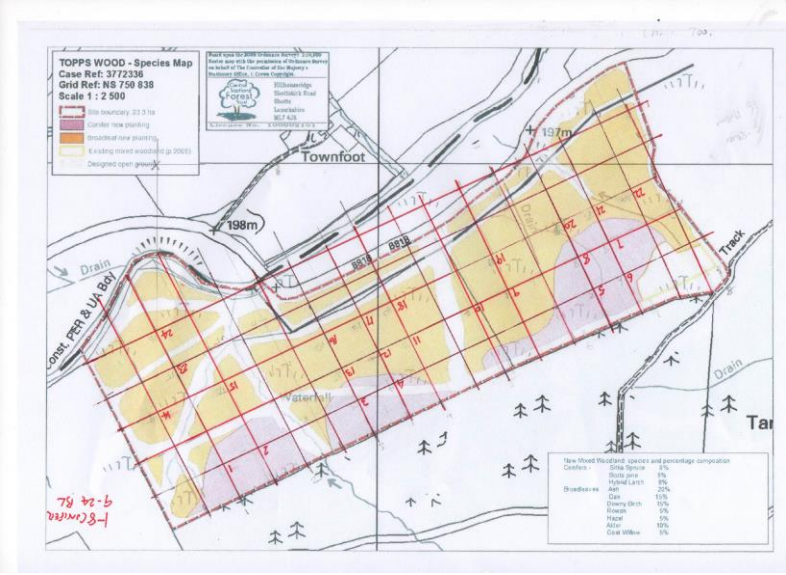
~~You may wish to do more than~~ This is the minimum number of plots you are required to complete. If your site is variable and~~if~~ the variation within your strata~~um~~ is high, i~~. I~~ncreasing the number of plots in a stratum (up to 30 per stratum) improves the accuracy and reduces the level of uncertainty in your results. ~~reduces the probability that survey results will be unrepresentative (e.g. the average stocking density of the plots diverging from the stratum stocking density).~~

2. Decide where to place the indicated number of plots. The plots should be randomly located across the relevant area, with the entire plot not within 5m of the edge of a stand/the woodland. You should record the locations/ grid references of each plot location before going to the site. This can be done, for example, by placing a regular grid across the project area and selecting 'nodes' which occur within the planted area (see figure 2) or by randomly selecting points spread throughout the planted area (see figure 1).

   Note: You should not change the location of your plots when you get on site. If your project has unmapped open ground and your plot falls in an unplanted or low-density area, you should account for this with additional plots (see table 3 above).

3. **Enter the details of your stratification into the 'planning – stratification' tab** of the monitoring report (for year 5 or 15+).

Figure 2: Example of plot selection for the Topps Wood project, which was made up of two strata – a conifer 'uniform' stratum (2 to 10ha) with eight plots and a broadleaved 'variable' stratum (10ha+) with 16 plots. In this case, the open ground within the project was clearly mapped.



4. Survey plan check

The survey plan must be accepted by your chosen verification body before undertaking the survey. You should submit the following documents to your chosen verification body as a minimum to get your survey plan check:

1. Woodland Carbon Code map from validation, plus any update, if for example, you are now able to update with areas of open ground.
2. Carbon calculation from validation.
3. At least the 'survey planning' tab from the monitoring report
4. A plot map which clearly shows how the site is stratified and the location of plots within each stratum.

The verification body could ask you to re-survey if:

- You do not get your survey plan checked
- Your survey plan is checked but it was based on incorrect information
- Your survey plan is not implemented according to the plan (allowing for practical adjustments made once onsite, e.g. it would be acceptable to choose to use a larger plot size if stocking density is not as good as planned).

5. Survey: plot setup and photography

Template monitoring reports are available (see template documents). These contain:

- Template data collection sheets (which can be printed or used on a suitable device)
- Summary sheet to calculation the stocking density (automated at year 5)
- Summary sheets to help calculate the carbon stock (semi-automated for year 15)

Before you head out to survey, make sure your survey plan has been approved by your chosen verification body.

5.0 Equipment you will need:

For all surveys, you will need:

- Map of the site with plot locations for each stratum indicated
- Sufficient blank stratum level data collection sheets (for year 5) or seedling/sapling/tree sheets (for year 15+), possibly printed on weather-resistant paper or loaded on a device suitable for outdoor use e.g. Toughbook.

- A Weather Writer or other waterproof clipboard if using paper sheets
- A pencil or pen with waterproof ink
- A tape or a cane marked at 0.1m intervals to assess tree height (including 1.3m for dbh measurements).
- A length tape (such as a 20 or 30 m logger's tape) suitable for laying out sample plots and measuring other horizontal distances
- Rope to use to indicate plot radius
- Spray paint or tape to mark central trees or plots
- Compass and/or GPS device (Garmin, other GPS or smartphone) to help navigate to each plot.
- Camera/smartphone/smartwatch or GPS device which can record the location/eight figure grid reference of the plot. Smartphone apps such as 'OS Locate' or 'Grid Reference' will give the current location as 6, 8 or 10-figure grid reference
- A camera / smartphone camera with location-tagging capability. Most smartphone cameras and newer cameras have location-tagging capability and can tag a photo with its latitude/longitude
- Painted stakes/canes/pegs to mark the location of plots (royal blue or white are effective).

For survey from year 15 onwards, you will also need:

- A rounded-down girth tape or tree callipers (for measuring tree diameters at breast height)
- A hypsometer or clinometer (for measuring tree height)
- Personal protective equipment: helmet with a visor or safety glasses if you are likely to be surveying in dense conifers.

5.1 Boundary and planting maps and 'whole site' site photographs

- **Before you go to site:** If there are any changes to your project net area or the species planted, create a new map to confirm the actual planted area. This should show any changes to the boundary, compartments within the site or change to areas allocated as open ground and needs to be submitted as part of your verification documentation. Refer to the latest mapping rules.
- Two things will be useful to help you decide where to locate plots and to confirm the 'actual' versus 'planned' net planted area:
  a. Any site maps produced between validation and this survey may help. If any boundaries or species planted differ to those given at the time of validation, amend the project areas/species and produce a new map.
  b. From year 15 onwards, access the latest aerial photography (or other remotely sensed data) where the planted area is visible and map the actual planted area, and update boundaries of the visible 'net planted area'.

There are a number of tools available to help with this task, which allow you to access aerial photography, including:

- England's Map Browser and Land Information Search
- Scotland's Land Information Search in Scotland's Environment Web
- Natural Resources Wales Interactive Mapper
- My Forest (you can upload an existing shapefile and overlay it on aerial photography)
- The Land App (access Bing imagery or Mapbox imagery)
- MAGIC
- Scotland's Environment Web
- Google Maps or Bing Maps (although aerial photography can be older).

When you are onsite: Where it is feasible, check that the boundaries on the ground agree with the mapped boundaries shown at validation or the most recent verification. Annotate any areas known to be left unplanted or which are now open/without trees for any reason.

Onsite photos: While onsite, take two or three photos across the whole site which are representative of the general site condition. Tag the location and note which direction ~~in which~~ the photo faces ~~was taken~~.

5.2 Locating plots and plot photographs

1. Navigate to each plot location in turn, using GPS device/smartphone app or map and compass.
2. ~~If open ground is mapped, and you find that the target plot location is in or on the edge of a mapped ride or other open area, then move the plot **up to 10m** so that it sits within a planted area. Note the change of location on the data collection sheet in the 'General Comments' box.~~
3. ~~2.~~ ~~If open ground is not mapped,~~ **Do not move plots** ~~**if they occur within an unplanted or low density planted area**~~ **as this will bias results.** ~~You will need to complete more plots, with the expectation that some of them will fall in more open areas with few or no trees (See Table 23).~~ You should still complete a plot sheet even if there are no trees in the plot location~~if this is the case~~.
4. ~~3.~~ Mark with a stake/peg the centre of a circular plot or south-west corner of a square plot, even if it does not contain any trees (see 3). It is also possible to mark the closest tree to the centre with spray paint/tape. If you do this, you should note on the survey sheet the distance and direction of the plot centre from the marked tree.
5. ~~4.~~ For each plot, stand at the stake/peg (centre of a circular plot or south-west corner of a square plot) and take a photograph.
    a. Ensure location-tagging is enabled so the latitude/longitude of the photo is embedded within the 'details' of the image. This is possible with smartphones and newer digital cameras.
    b. Record the time (to help with photo-to-plot matching) and the direction ~~in~~ which the photograph faces ~~was taken from~~. It may be feasible to take all

photographs facing the same direction (e.g. all to the north). Also consider making the plot sheet visible in the very corner of the image so there is a record of the plot number on the photo.

~~6.~~5. If you have not recorded the location of the plot via photo location-tag, record at least an eight figure grid reference using a GPS device (Garmin or other) or suitable smartphone app.

~~7.~~6. Use measuring tape/rope and spray paint to locate and mark the boundary of the plot or use measured rope as a ‘spoke’ to identify radius as you work your way round the plot. A retractable dog-lead marked with standard radius options is an option.

6. Year 5 survey: stocking density and tree health

Before you go to site: Adding certain information about each stratum to the relevant 'stratum summary sheet' will update all the 'plot sheets' for the information that is the same across the stratum (see the year 5 monitoring report). It will also pre-populate the likely species list that you will be monitoring at each plot.

6.1 Stocking density

1. Within each sample plot, count and record the number of both live and dead seedlings/saplings of each species.
2. Note the number of live trees damaged.
3. Specify the main reasons for damaged or dead trees in the plot. E.g. due to deer browsing, deer fraying, sheep/goat browsing, vole, rabbit, weevil or other pest damage, human or other damage or disease.

6.2 Tree growth and health

Tree growth

Assess the overall growth of the seedlings/saplings by assessing within each plot:

1. Number of seedlings/saplings with:
   - Poor leader growth (last year's leader growth is less than the average to date)
   - Multiple stems
   - Poor leaf/needle size
   - Poor lead/needle retention

2. Estimate the height of each live tree:

   - to the nearest 0.1m below 1m (e.g. 0.6m, 0.7m, 0.8m, 0.9m and 1.0m) and
   - to the nearest 0.5m above 1.0m (e.g. 1.5 and 2.0).

If tree shelters are used and the height of shelters is known, this is a helpful guide. A cane painted in 0.1m intervals is also a useful tool to help gauge height.

3. Add any observations/ reasons for poor growth in the 'general comments' box at the bottom of the plot sheet.

Tree health

Assess the overall health of the seedlings/saplings by assessing within each plot:

1. Number of seedlings/saplings with:

   - Poor foliage colour or needle/leaf size
   - Poor needle or leaf retention

2. Number of seedlings/saplings suppressed by weeds
3. Specify the main weeds which are a problem within the plot E.g.: heather, thistle, bramble, willowherb, nettle, juncus/rushes, bracken, gorse/broom, rhododendron, grass.
4. Add any observations/ reasons for poor health or vigour in the 'general comments' box at the bottom of the plot sheet.

Example 1: Recording tree growth and health

	HEIGHT (nearest 0.1m < 1.0m, nearest 0.5m > 1.0m) LIVE LOCATIONS																Growth/ Health: *Enter 'Y'*				
Seedling/ Sapling No:	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Species 8	Species 9	Species 10	Species 11	Species 12	Species 13	Species 14	Species 15	Damaged? *Enter 'Y'*	Poor leader growth	Multiple stems	Poor needle/ leaf size	Poor needle/leaf retention	Suppressed by weeds? *Enter 'Y'*
1																					
2																					
3																					

General Comments : Insert comments on ground preparation, health of trees, reasons for understocking, lack of vigour, foliage colour etc…

6.4 Tree protection

For each stratum as a whole, on the 'stratum summary sheet', note the presence or condition of:

1. Tree shelters/individual tree protection –
   - Presence (Yes/No)
   - Condition
     - Good – all shelters in good condition
     - Average – some missing or damaged but majority intact
     - Poor – majority missing, not installed correctly or damaged
     - Outgrown – shelters need removing

2. Fencing –
   - Presence (Yes/No)
   - Condition
     - Good – Fencing in perfect condition
     - Poor – Requiring attention (specify detail)

3. General comments – Please add any other comments relating to the ground preparation, health of trees, reasons for understocking, lack of vigour, foliage colour etc.

Example 2: Recording tree shelter, fencing and other general comments for the stratum.

Tree Protection	Presence? (Y/N)	Condition	Comments
Tree Shelters	Y	Pick from list	
Fencing	Y	Pick from list	
General Comments : Insert comments on ground preparation, health of trees, reasons for understocking, lack of vigour, foliage colour etc...			

7. Year 5: overall stocking density and tree health

The year 5 monitoring report will automatically carry out further calculations if data is entered into each 'plot survey sheet'. You can enter data into the data sheets in the field if you have a suitable device or back in the office if you take paper sheets to site.

- **You will need one monitoring report per stratum.**
- Basic information such as project name, ID, stratum number and net area, number of plots should be entered into the stratum summary sheet and will copy across to each plot sheet.
- The stratum summary sheet automatically updates and calculates the stocking density.
- Remember to add any general comments about each plot in terms of ground prep, health of trees, reasons for understocking or lack of vigour or foliage colour etc. There is also a space in the stratum summary sheet for general comments which apply to the whole stratum.

7.1 Results for each stratum:

The stratum summary sheet of the year 5 monitoring report gives the following results:

- **Actual planting density compared to planned** is given in Cells AA2 to AE5 (top right). The metrics shown give an idea of how variable the stocking density across the site as well as giving the overall stocking density. If the overall actual stocking density is less than 90% of the planned stocking density, you will be asked to provide a remedial plan. Your project will be classed as amber or red depending on the severity of the shortfall.

% plots 10% over planting density	**85.0%**
% plots at planned planting density	**95.0%**
% plots within 10% of planting density	**100.0%**
Overall actual versus planned planting density	**95.0%**

- **The difference between the planned and actual species mix** is given in cells B36 to Q39. This is helpful to understand if the carbon prediction is representative of the actual mix.

Actual species mix (%)	55%	18%	27%	10%			100%
Planned species mix (%)	50%	20%	20%	10%			**100%**
Planned species area (ha)	5.0	2.0	2.0	1.0			**10.0**
Difference (% point)	+5%	-2%	+7%	0%			0%

- **Growth and health:** Summary statistics for trees damaged or dead with the reason, tree growth and health metrics as well as any issues with weed suppression are also summarised to give a general picture of the health of the site and to identify any potential issues that need to be addressed.
- **Tree protection:** (in terms of fencing or tree shelters) is also given to help identify any issues and help with ongoing management.
- **General comments:** should be entered if there are any specific issues onsite

7.2 Summary of calculations

This section summarises the calculations which are made in the stratum summary sheet of the year 5 monitoring report.

7.2.1 Stocking density

1. For each stratum, separately by species, estimate the **number of seedlings/saplings of each species per hectare** by adding together the total number of seedlings sampled and dividing by the total area of all the sample plots used.

2. For each stratum, estimate the **total seedling/sapling per hectare count** by summing the seedling/sapling per hectare figure for each species**.**

7.2.2 Compare predicted and actual stocking density

For each stratum, compare the predicted stocking density (as per the project design document) with the actual stocking density as indicated by the survey results.

Provided there are **less than 10% evenly distributed losses**, it will not normally be necessary to intervene as this is considered an acceptable minimum for beating up, but remember that the distribution of these losses is just as important. Losses confined to a particular area leaving a ‘gap’ should be beaten up.

Provided the actual stocking density is at least 90% of the planned stocking density, we will assume that the carbon sequestration of the project at year 5 is as predicted and there is no under- or over- delivery at this stage. If the overall actual stocking density is less than 90% of the planned stocking density, you will be asked to provide

a remedial plan. Your project will be classed as amber or red depending on the severity of the shortfall.

7.2.3 Tree growth

For leader growth and multiple stems

For each stratum, calculate the number of seedlings/saplings per hectare exhibiting poor growth by adding together the total number of seedlings sampled exhibiting poor leader growth or multiple stems and dividing by the total area of all the sample plots used.

Tree height

For each stratum, separately by species, calculate the average height of the sampled seedlings/saplings.

7.2.4 Tree health

For each stratum, calculate the number of seedlings/saplings per hectare exhibiting each health indicator (foliage colour, foliage size, browsing or fraying damage, weed competition) by adding together the total number of seedlings/saplings sampled exhibiting that indicator and dividing by the total area of all the sample plots used.

8. Year 15+ survey: measuring trees from year 15 onwards

Sample trees are allocated to either the seedlings, saplings or trees. Each category should be sampled separately according to the methods below, and subsequent calculations carried out as specified in section 8. The plot-based results are used to derive per hectare values for each tree category which are then scaled up to the net size of the stratum.

This guide describes how to monitor broadleaves and conifers according to methods B (broadleaves) and C (conifers) from the carbon assessment protocol.

Before you go to site:

There are a few things to plan before you go to site. The main consideration is how many species are likely to be present in the stratum and how you will 'group' these when you survey.

Each 'major' species is assessed separately within each plot, but where a species constitutes less than 10% of the total tree numbers, this should be treated as a "minor species" and grouped with the most similar alternative species present in the woodland as follows:[1]

1. Try to group minor species with the largest principal species component by genus. For example, group pines together, group spruces together, group oaks together etc.
2. If (1) fails, try to group minor species with the largest principal species component by the following genus groups:
   a. Pines, larches
   b. Spruces, coast redwood, Wellingtonia (giant sequoia), Douglas fir, firs
   c. Western red cedar, Western hemlock, cypresses
   d. Oak, ash, beech, alder, elm, hornbeam, nothofagus, chestnut
   e. Birch, cherry, poplars, maples/sycamore, hazel.
3. If step 2 fails, group minor species with the largest principal species component by phylum/type:
   a. Conifers with conifers
   b. Broadleaves with broadleaves.

The tab 'planning – stratumx _species' in the year 15+ monitoring report provides space to look at your species mix and decide how to group your species.

[1] OGB 9 (Managing) Thinning and "Stand tariff from top height" in Table A7.1 in Forest Mensuration (2006).

At each plot, you will need a ‘seedlings,’ a ‘saplings’ sheet plus a ‘tree’ sheet for each species/ species group.

8.1 Seedlings

At each sampling point, count and record the number of living seedlings of both conifer and broadleaves within a 5.6 metre radius (0.01 hectare) sample plot. Note the main conifer or broadleaf species in each plot. Using a ruler, estimate and record the height (in centimetres, to the nearest 10cm) of the three conifer and three broadleaf seedlings closest to the centre of each plot. Where there are fewer than three conifer or three broadleaf seedlings, you should measure the heights of all.

Example 3: Seedling count and height:

BROADLEAVES		** Only measure the 3 Broadleaves closest to the centre			
Plot NO	Main Species (list one)	No of seedlings	Tree heights (cm)		
			1	2	3
1					
2					
3					

CONIFERS		** Only measure the 3 Broadleaves closest to the centre			
Plot NO	Main Species	No of seedlings	Tree heights (cm)		
			1	2	3
1					
2					
3					

8.2 Saplings

At each sampling point, count and record the number of living conifer and broadleaf saplings within a 5.6 metre radius (0.01 hectare) sample plot. Measure and record the heights of the three conifer and three broadleaf saplings closest to the centre of each plot (to the nearest 0.1m). Note the main conifer/broadleaf species in the plot. Where there are fewer than three conifer or three broadleaf saplings, you should measure the heights of all.

Example 4: Sapling count and height:

BROADLEAVES		** Only measure the 3 Broadleaves closest to the centre			
Plot NO	Main Species	No of saplings	Tree heights measured (m)		
			1	2	3
1					
2					
3					

CONIFERS		** Only measure the 3 conifers closest to the centre			
Plot NO	Main Species	No of saplings	Tree heights measured (m)		
			1	2	3
1					
2					
3					

8.3 Trees

This is the default method for assessing strata containing broadleaved or conifer trees or a mixture of species. Dbh and height should be measured by species.Where a species constitutes less than 10% of the total tree numbers, this should be treated as a “minor species” and grouped with the most similar alternative present in the woodland.

1. Within each plot, measure and record by species/species group the dbh of every living tree where this is seven centimetres or greater.

Example 5: Recording diameter at breast height

Count of number of trees by DBH (round down)								
	Plot Number							
DBH (cm)	1	2	3	4	5	6	7	8
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								

2. Identify the two trees of each species/species group nearest to the plot centre. These will be your height sample trees. If species are grouped, these should be two trees of the 'main' species.

3. Measure and record dbh and the height of the two sample trees of each species.

- For broadleaves, measure the timber height (the distance from the base of the tree to the lowest point on the main stem where the diameter is at least 7cm. This point may be the 'spring of the crown' – the lowest point at which no main stem is distinguishable).
- For conifers, measure the total height (the distance from the base of the tree to the uppermost point/tip)

You can measure the height of young trees with graduated poles. Larger trees should be measured with a manual or electronic hypsometer or clinometer, following the instructions supplied with the instrument. Each tree should ideally be measured from opposite sites perpendicular to any lean, and the two measurements averaged. The distance from the tree to the observation point should be 1 to 1.5 times the height of the tree. Accurate use of hypsometers of clinometers requires training, checking and practice.

Example 6: Recording tree height data

Plot Number	Species	DBH (cm)	Total Height (Conifer) or Timber Height (Broadleaves) (m)	Tarriff Number (rounded)
1				0.0
1				0.0
2				0.0
2				0.0
3				0.0
3				0.0
4				0.0
4				0.0
5				0.0
5				0.0
6				0.0
6				0.0

8.4 Tree growth and health

For the plot as a whole, note any concerns or issues with tree health, recording the species and number of trees affected. This could include leader growth or multi-stemmed trees, foliage health, browsing or other pests/diseases, weeds or windblow.

8.5 Tree protection

For the stratum as a whole, note any observations about tree protection (either state of fencing or tree guards).

Example 7: Recording any general information on tree growth/health and protection

General Comments on Tree Growth & Health or Tree Protection (eg leader growth, multi-stemmed trees, foliage health, browsing or pest/disease, weeds or windblow, state of fencing or tree guards) - For the whole stratum

9 Year 15+: Overall carbon stock and tree health

9.1 Using the monitoring report to calculate carbon stock and compare to prediction:

The year 15+ monitoring report will semi-automatically carry out further calculations if data is entered into the relevant sheet. You can enter data direct into the data sheets in the field if you have a suitable device or back in the office if you take paper sheets to site.

- You will need one monitoring report per stratum.
- The stratum_species sheet will help you to identify the species groups you will use to survey. It also has a space to note the grid reference of each plot that you survey.
- You need one seedling and sapling sheet for each stratum and one tree species sheet per species group in the stratum. Once you enter the relevant details into these sheets, the carbon content of that element will be calculated automatically.
- The project total carbon sheet provides a space to add together all the elements of each stratum across your project (e.g. the seedlings, saplings and tree species across each stratum in the project).

Example 8: Summarising the elements of each stratum across the project

Seedling, Sapling or Tree species in the stratum	Tree species group	Stratum 1 - tCO2e	Stratum 2 - tCO2e	Stratum 3 - tCO2e	Stratum 4 - tCO2e	Total CO2e
Seedlings		0.0	0.0	0.0	0.0	0
Saplings		0.0	0.0	0.0	0.0	0
Tree species 1	[insert species name]	0.0	0.0	0.0	0.0	0
Tree species 3	[insert species name]	0.0	0.0	0.0	0.0	0
Tree species 4	[insert species name]	0.0	0.0	0.0	0.0	0
Tree species 5	[insert species name]	0.0	0.0	0.0	0.0	0
Total CO2 sequestered to date		0	0	0	0	0

- The project total carbon sheet also provides a space to compare your actual survey result with the predicted carbon sequestration at that point in time. On first use, you will need to copy and paste information from the validated carbon calculator used at validation into the sheet to make the comparison. This allows us to adjust for any elements considered in the original prediction (e.g. emissions from establishment, baseline and leakage estimates and soil carbon losses/sequestration). It also allows us to allocate 20% of the actual sequestered carbon to the buffer.

- The project total carbon sheet also provides a space to state the predicted and actual Pending Issuance Units for the given vintage. Once completed, this information needs to be copied back into your project progress report.

Example 9: Planned and actual units delivered within the vintage under assessment

Vintage start date:	1/4/2015	Vintage end date:	1/4/2020
	Total units in vintage (tCO2e)	Units to buffer (tCO2e)	Units to project (tCO2e)
Predicted units (PIUs) in vintage being assessed	**100**	**20**	**80**
Actual units (WCUs) in vintage being assessed	**120**	**24**	**96**
PIUs to be cancelled			
Extra WCUs to be issued	20	4	16

9.2 Summary of calculations

This section summarises the calculations which are made in the year 15+ monitoring report. For more information, refer to the carbon assessment protocol methods B and C.

Seedlings

For the conifer and broadleaved seedlings, calculate the average height of seedlings in the stratum and lookup the carbon content using the relevant table. Convert carbon to carbon dioxide. Sum the conifer and broadleaved seedlings.

Saplings

For conifer and broadleaved saplings, calculate the average height. This will be our estimate of height of the representative sapling of each species. Look up the carbon content using the relevant table. Convert carbon to carbon dioxide. Sum the conifer and broadleaved saplings.

Trees

We need to estimate the biomass in the stem, crown and roots and then add up~~sum~~ these components and convert mass to tonnes of carbon dioxide equivalent.

1. For the stratum by species/species group (if grouped), estimate the total number of trees in the stratum.

2. For the stratum by species/species group, calculate the quadratic mean dbh and mean basal area. These will be used in subsequent calculations.

3. For each height sample tree of each species/species group, find the appropriate tariff number. The equation varies by species, within conifers and broadleaves.

4. For the stratum by species/species group, calculate the mean merchantable tree volume and the mean total stem volume and multiply by the number of trees to get the total stem volume in the stratum, by species/species group.

5. For the stratum by species/species group, estimate the total biomass content of the tree stem, crown and root components. Equations are different for conifers and broadleaves, within groupings of species.

6. For the stratum by species/species group, estimate the total biomass in the stratum by summing the stem, crown and root biomass components.

7. Add together the total biomass of each stratum to get the total biomass of the trees and then convert the total biomass to total carbon dioxide equivalent.

8. Add together the carbon dioxide equivalent content of the seedlings, saplings and each trees species group to arrive at a ‘total above and below ground biomass carbon dioxide’ figure. In the project total carbon tab.

8. Compare with your carbon prediction and take account of the emissions from soil carbon, emissions from establishment, clearfell to come up with an adjusted carbon stock.

9. Compare the actual carbon stock with the value at the last verification to work out the amount sequestered in the current vintage. Complete the ‘planned and actual units delivered within vintage under assessment’ table and copy this back into your project progress report.

Annex 1: Calculating plot size on sloped ground

If the ground to be surveyed is at a significant slope, you may need to increase the plot size to account for measuring at an angle. Table A1 shows the size of plot you should use on sloped ground, for common plot sizes on flat ground. For example, if you would normally use a 5.6m radius plot on flat ground, you should increase the radius to 6.2m where the slope is 25º.

Table A1: Plot radius at various slope angles for common 'flat ground' plot sizes (5.6m, 8m and 12.6m)

Radius on flat ground	5.6	8	12.6
Adjusted radius at 25º slope	6.2	8.8	13.9
Adjusted radius at 30º slope	6.5	9.2	14.5
Adjusted radius at 35º slope	6.8	9.8	15.4
Adjusted radius at 40º slope	7.3	10.4	16.4
Adjusted radius at 45º slope	7.9	11.3	17.8

Example: If you need to calculate the plot radius for a different 'flat ground' plot radius or slope, then follow this formula email info@woodlandcarboncode.org.uk ~~for further~~ or further advice.

Flat ground radius x 1/cos(angle) = sloped ground radius

For example:

8m x 1/cos(45º) = slope radius

8m x 1.4142 = slope radius

8m x 1.4142 = 11.3m plot radius on 45º ground.