

SKÓGARKOLEFNI

# Survey Methods

## *Guidance for surveys in Skógarkolefni projects*

Version 2.2.1

Based on the Survey Protocol for Woodland Carbon Code projects, version 3.0.1 (July 2026), and Icelandic forestry research.

### About this guidance

This document describes methods for planning and carrying out surveys of carbon sequestration and forest development in Skógarkolefni projects, as well as processing the results. The choice of method depends, among other things, on project size and heterogeneity, planting density, species composition, forest age and accessibility.

Survey technology for plantations and forests is developing rapidly, so survey methods are likely to change in the coming years. It is appropriate for new, recognised technologies to replace the methods described in this guidance.

**Important:** The survey plan must be reviewed by a certification body before field measurements begin. Any departure from the approved plan must be recorded and justified.

### Contents

1. Overview of the survey process
2. Survey plan
3. Preparation and fieldwork
4. Year 5 survey

5. Survey in year 10 or later
6. Results and calculation of carbon stocks
7. Appendix A. Plot correction for slope
8. References

## 1. Overview of the survey process

The survey comprises three main stages:

1. Plan the survey: stratify the site, select plots, determine their number and locations, and submit the survey plan for review.
2. Carry out the field survey: locate and photograph plots, and count or measure young plants and trees.
3. Process the results: enter the data in a spreadsheet and IceForest, calculate planting density (after 5 years) or carbon stocks (after 10 years or later), assess the general condition of the trees, and compare measured carbon stocks with the projection.

After the survey, the project manager submits a progress report and any other required information to the certification body.

## 2. Survey plan

### 2.1 Site stratification

Before a survey begins, it may be useful to divide the project area into relatively uniform survey strata. This can reduce the number of plots in the sample and the variability in the data. Variation within each stratum should be lower than variation between strata. Stratification may change as the forest ages, as species composition, growth rate and density often become more apparent over time.

1. Use an up-to-date map showing the overall project boundary, planted areas, areas of natural regeneration, open areas, roads, streams and pre-existing woodland.
2. Map open areas larger than 0.25 ha and exclude them when defining survey strata. If open areas have not been mapped, increase the number of plots.
3. Divide planted areas into survey strata, for example by baseline mapping, planting year, species or species mixture, growth rate and density, as appropriate.

Where overall uniformity is lacking or information about planting is insufficient, stratifying the project area may be of little value.

The following general principles may be used when stratifying areas:

1. Separate areas of natural regeneration from planted areas.
2. Mixed woodland may form one stratum if the species occur as an intimate mixture, in rows, groups or a mosaic.

3. Areas with variable planting density may form one stratum.
4. A small area of up to 2 ha and less than 5% of the project's net area may be combined with the stratum it most closely resembles.

A stratum is considered uniform when all the following conditions are met:

1. Planting took place within a three-year period and differences in tree height do not exceed approximately 3 m.
2. The stratum consists mainly of one species.
3. Plants are evenly distributed and not clustered.

If one or more conditions are not met, the stratum is considered variable and more plots are required.

## 2.2 Plot size and shape

Circular plots of 100 m<sup>2</sup> are recommended for surveys (radius 5.64 m). If there is a specific reason to use plots of a different size, explain it in the survey plan. Plot size must be consistent within each survey stratum. Where the slope is approximately 25° or greater, correct the plot radius; see Appendix A.

## 2.3 Number and location of plots

The minimum number of plots depends on the net area of the stratum, its variability, and whether open areas or pre-existing woodland have been mapped.

*Table 1. Minimum number of plots*

| Net area of stratum | Uniform stratum | Variable stratum; plots mapped | Variable stratum; <20% unmapped | Variable stratum; ≥20% unmapped |
|---------------------|-----------------|--------------------------------|---------------------------------|---------------------------------|
| < 0.5 ha            | 4               | 6                              | 7                               | 8                               |
| 0.5–2.0 ha          | 6               | 8                              | 9                               | 10                              |
| 2.0–10.0 ha         | 8               | 12                             | 14                              | 16                              |
| > 10.0 ha           | 10              | 16                             | 19                              | 21                              |

1. The numbers in the table are minimums. Where variability is high, the number may be increased to as many as 30 plots per stratum to improve precision and reduce uncertainty. If survey strata could not be adequately defined and located, still more plots may be needed to obtain a meaningful result. Allow for a generous number of plots in case any must be excluded from the sample (see below).
2. Plot locations should preferably be selected using systematic random sampling (equal spacing between plots) across the entire stratum, and the coordinates should be recorded before fieldwork begins. The same method may be used where the area has not been divided into survey strata.
3. To prevent plots from overlapping between strata or extending beyond the woodland, a buffer slightly wider than the plot radius may be set along the boundaries of each stratum. During the field work, a plot found to lie partly or wholly outside its mapped stratum should be excluded from the survey.

4. When preparing the survey plan, avoid placing plots where conditions could endanger the survey team, for example on very steep slopes or in areas at risk of landslides. Any changes to the survey plan must be justified.
5. During field work, a plot found to be in a location that endangers the survey team may be excluded from the survey.
6. Record why a plot is excluded during the fieldwork, whether it is inaccessible or lies partly outside the mapped stratum being assessed.

**Do not move a plot to find more trees.** A plot that falls in an unplanted or sparsely stocked area remains part of the sample if it lies within a mapped planting area. A plot may be excluded only where safety requires it or where fieldwork shows that it lies partly outside the mapped planting area.

## 2.4 Review of the survey plan

Before measurements begin, send the following documents to the certification body:

1. a completed survey plan
2. the latest project map, together with a description of any updates
3. the carbon calculation used at validation and, where applicable, an updated calculation
4. evidence and justification for any changes to the carbon calculation
5. a map showing survey strata and the location of plots within each stratum

The certification body may require measurements to be repeated if the survey plan was not reviewed, was based on incorrect information or was not followed. Record all changes to the plan, such as enlarging plots if density is lower than expected.

## 3. Preparation and fieldwork

### 3.1 Required equipment

The following equipment is required for all surveys:

1. a map showing survey strata and the proposed plot locations (usually on a field computer)
2. a data-recording device suitable for outdoor use (field computer)
3. a measuring pole or suitable instrument for measuring height
4. callipers or a diameter tape
5. a measuring instrument or tape measure for laying out plots
6. stakes or pegs, and marking tape or spray paint, for marking the plot centre
7. an accurate GPS device with plot coordinates
8. a camera or cellphone

For surveys in year 10 or later, also bring callipers or a diameter tape, a height meter and suitable personal protective equipment, including eye protection or a helmet where dense woodland or other conditions require it.

### 3.2 Maps and overview photographs

1. Update maps if boundaries, net area, species composition or open areas have changed.
2. From year 10 onwards, compare the latest aerial imagery or other remote-sensing data with the project boundaries.
3. Where possible, confirm in the field that the mapped boundaries match actual conditions and mark any unplanted or treeless areas.
4. Take two or three overview photographs showing the general condition of the site. Record coordinates, time and camera direction. It is preferable to take all photographs in the same direction, for example from south to north to avoid taking them in the sun's direction.

### 3.3 Plot establishment and photography

1. Locate the centre of the plot using a GPS device.
2. Once the location has been found, record the plot coordinates by averaging the position for at least 60 seconds. Enter the plot number as the plot name in the GPS device.
3. Do not move a plot because it is sparsely stocked or treeless. Record it even if it contains no trees.
4. Mark the centre of the plot with a stake or peg.
5. Take a photograph from the centre of the plot, pointing the camera north. Enable geotagging and record the time and plot number.
6. Mark out the plot area using a suitable instrument, or a tape or measured rope, and use it as the radius while walking around the circumference.

## 4. Year 5 survey

The year 5 survey confirms plant density, growth and condition. The same method may be used for a survey in year 10 if plants have not reached sufficient size for their carbon sequestration to be assessed.

### 4.1 Plant density

1. Count and record living plants by species within each plot and assess their height.
2. Record the number of damaged living plants and dead plants. Record a plant as “missing” if it cannot be found.
3. Assess the causes of damage or mortality where possible.
4. Where self-seeding or natural regeneration is very dense and more than 60 plants occur in a plot, counting may stop at 60 and the total number may be estimated in the notes.

### 4.2 Growth, condition and protection

For each plot, record the number of plants showing the following defects or signs of poor condition:

1. slow leader growth compared with previous years
2. leader dieback
3. multiple stems
4. abnormally small or yellowing leaves or needles
5. poor leaf development
6. competition from other vegetation

Also record likely causes of poor condition, such as browsing, frost, wind, drought, insects, disease, human damage or competition. Describe the condition of fencing if browsing damage is present.

### 4.3 Results and assessment of progress

Enter the data from each plot into a spreadsheet or the program IceForest. Keep survey strata separate and report the results.

The summary should show:

1. plant density compared with the original density
2. the distribution of density among plots and areas
3. species composition compared with the management plan
4. the amount of poorly thriving plants and dead plants, and the main causes
5. growth, health, competing vegetation and the state of protective measures

**Assessment of infill planting needs:** If the initial planting density was about 2,500 plants per hectare and mortality is below 10% and evenly distributed, infill planting is usually unnecessary. The need is greater where the initial planting density was lower. Local gaps may require infill planting even if overall density is adequate. High density in one location does not compensate for gaps elsewhere.

A project is rated green, amber, red or unconfirmed under the current Skógarkolefni criteria (see chapter 2.5: Verification ratings and issuance of units). The assessment considers density, growth and health. An amber or red rating will normally require a remedial action plan.

## 5. Survey in year 10 or later

A survey in year 10 or later confirms the carbon stock in tree biomass at a specified point in time and also assesses woodland growth, health and protection. If plants are still small and growing slowly, the year 5 method may be used.

### 5.1 Preparation and species groups

Review previous surveys and the projected species composition. Assess each principal species separately. A species accounting for less than 10% of all stems may be combined with a comparable species in the following order of priority:

1. First, combine species from the same genus, for example pine species with one another or spruce species with one another.
2. If the group still accounts for less than 10%, combine species with similar growth rates that use comparable biomass models. IceForest is recommended for this comparison (see below).
3. If the group still accounts for less than 10%, conifers may be combined with conifers and broadleaves with broadleaves, provided the current equations allow it.

**Species groups must be confirmed.** The choice of groups can affect biomass coefficients and carbon calculations. Record the assumptions and have any unusual grouping reviewed before measurements begin.

## 5.2 Young plants (height ≤ 1.5 m)

1. Count living plants within each plot and record the species.
2. Measure the root-collar diameter and height of all plants.

## 5.3 Trees (height > 1.5 m)

1. Count living trees within each plot and measure diameter at breast height (1.3 m), or at the height required by the applicable biomass model (0.5 m for birch, rowan and willow species). Record the measurement height.
2. Select the largest-diameter tree in the plot and measure its height.
3. Exclude large trees that can be shown to have been present before the project began.

When measuring tree height, place yourself approximately 1–1.5 tree heights away from the tree.

Where a tree leans, it is preferable to measure from two opposite sides at right angles to the direction of lean and use the mean. Accurate use of instruments for measuring tree height requires training.

## 5.4 Protection, growth and condition

Describe likely causes of poor growth or high mortality. Describe the condition of fencing if browsing damage is present.

# 6. Results and calculation of carbon stocks

At year 5, use the carbon projection from the Skógarkolefni Calculator to assess the increase in carbon stocks. Young trees are generally too small for measurements of tree growth to produce meaningful results. If planting density, species composition and the planted area are as planned, and plant condition is acceptable, the previous estimate of carbon sequestration for the project's first verification period may be submitted to the certification body for verification. Update the carbon estimate if the assumptions are not met.

For surveys in year 10 or later, the IceForest program is recommended for calculating carbon stocks in each survey stratum and for the project as a whole. A licence to use the program is available from Timo

Pukkala ([timo.pukkala@uef.fi](mailto:timo.pukkala@uef.fi)). The program is used to assess forest carbon stocks and project their development. It uses growth equations for tree species in Iceland as well as equations for carbon stocks in tree root systems. Published equations for the above-ground biomass growth of different tree species are listed in Table 2. Equations for tree root systems are also included but have not yet been published.

## 6.1 Biomass models

The following equations can be used to calculate the biomass of trees and young plants in Icelandic projects. IceForest uses these equations together with root models.

### 6.1.1 Equations for plant biomass (height ≤ 1.5 m)

The above-ground biomass of young trees up to 1.5 m in height may be estimated using the following equation:

$$LB = g_{rh} \times 22.745 - 6.3406 \quad (1)$$

Here, LB is above-ground biomass in grams and  $g_{rh}$  is the cross-sectional area at the root collar in  $\text{cm}^2$  (Snorrason and Heiðarsson, 2021). The cross-sectional area of a circle is calculated by squaring its diameter, multiplying by pi ( $\pi \approx 3.14159$ ) and dividing by four:

$$\text{Cross-sectional area} = (\text{diameter}^2 \times \pi) / 4$$

The below-ground biomass of young trees up to 1.5 m in height may be estimated using a root-to-shoot ratio of 0.87 (Snorrason and Heiðarsson, 2021), as follows:

$$\text{Root biomass} = \text{above-ground biomass} \times 0.87 \quad (2)$$

### 6.1.2 Equations for tree biomass (height > 1.5 m)

The biomass of trees taller than 1.5 m is estimated using the equations in the table below.

**Table 2. Biomass functions for the principal tree species used in Icelandic forestry. LB denotes above-ground biomass and BGB denotes below-ground biomass in kg; d is diameter in cm at the specified measurement height, and h is main-stem length in m.**

| Species                                | Biomass functions                                   |
|----------------------------------------|-----------------------------------------------------|
| <b>Above-ground biomass</b>            |                                                     |
| Black cottonwood                       | $LB = 0.0717 d_{1.3}^{1.8322} h^{0.6397} \quad (3)$ |
| Sitka spruce and white spruce          | $LB = 0.1128 d_{1.3}^{1.7531} h^{0.6634} \quad (4)$ |
| Lodgepole pine                         | $LB = 0.1429 d_{1.3}^{1.8887} h^{0.4332} \quad (5)$ |
| Siberian larch                         | $LB = 0.1081 d_{1.3}^{1.53} h^{0.9482} \quad (6)$   |
| Norway spruce                          | $LB = 0.2465 d_{1.3}^{2.12} h^{-0.167} \quad (7)$   |
| Engelmann spruce                       | $LB = 0.9211 d_{1.3}^{1.438} h^{0.102} \quad (8)$   |
| Feltleaf willow and dark-leaved willow | $LB = 0.0348 d_{0.5}^{1.9123} h^{0.8904} \quad (9)$ |

| Species                                | Biomass functions                                                   |
|----------------------------------------|---------------------------------------------------------------------|
| Downy birch and rowan                  | $LB = 0.0634 d_{0.5}^{2.1552} h^{0.2877} (10)$                      |
| Downy birch (planted)                  | $LB = 0.123 \times (1 + d_{1.3})^{2.235} (11)$                      |
| <b>Below-ground biomass</b>            |                                                                     |
| Black cottonwood                       | $BGB = 0.0395510 d_{1.3}^2 (12)$                                    |
| Sitka spruce                           | $BGB = 0.03060 d_{1.3} d^{2.18166} (13)$                            |
| Lodgepole pine                         | $BGB = 0.025769 d_{1.3}^{2.270041} (14)$                            |
| Siberian larch                         | $BGB = 0.042765 d_{1.3}^2 (15)$                                     |
| Norway spruce                          | $BGB = 0.024078 d_{1.3}^{2.304068} (16)$                            |
| Engelmann spruce                       | $BGB = 0.0466158 d_{1.3}^2 (17)$                                    |
| Feltleaf willow and dark-leaved willow | $BGB = 0.0515293 d_{0.5}^2 (18)$                                    |
| Downy birch (natural)                  | $BGB = 0.0708543 d_{0.5}^2 (19)$<br>$BGB = 0.110704 d_{1.3}^2 (20)$ |
| Downy birch (planted)                  | $BGB = 0.0845137 d_{1.3}^2 (21)$                                    |

Sources for the equations: (3, 5–10) Snorrason, A. and Einarsson, S. F. (2006); (4) Heiðarsson, L., Nyström, K. and Snorrason, A. (2026); (11) Heiðarsson, L., Pukkala, T. and Snorrason, A. (2026); (12–21) unpublished equations provided by Lárus Heiðarsson.

If it is not possible to measure diameter at the specified height in year 10, equation (1) may be used even if the tree is taller than 1.5 m.

To convert biomass to CO<sub>2</sub> equivalent, multiply by 1.83.

## 6.2 Soil carbon

Simple, quick methods for assessing soil carbon have not been developed. The soil-carbon coefficients listed in the “Site types” tab of the Skógarkolefni Calculator (<https://reiknival.skogur.is/landgerdir/>) are therefore recommended for estimating soil-carbon accumulation. These coefficients are based on scientific data. In carbon-sequestration calculations, the estimated increase in soil carbon is added to the estimate of carbon in trees.

## 6.3 Comparison with the carbon sequestration forecast

1. Sum the measured carbon stocks within each survey stratum.
2. Sum the results from all survey strata and add the estimated increase in soil carbon for the project as a whole.
3. Compare the result with the carbon projection.
4. Account for factors included in the original projection, such as emissions from afforestation activities, the baseline carbon balance and leakage.

5. Compare projected and actual sequestration for the relevant monitoring period and include the result in the project progress report.
6. Update the carbon projection if species composition, density or growth differs substantially from previous assumptions.

## Appendix A. Plot correction for slope

On sloping ground, the horizontal area of a plot is smaller than the area measured along the ground surface. The plot radius must therefore be increased where the slope is approximately 25° or greater.

*Table A1. Corrected plot radius for slope*

| Slope | 5.6 m radius on level ground | 8.0 m radius on level ground |
|-------|------------------------------|------------------------------|
| 25°   | 6.2 m                        | 8.8 m                        |
| 30°   | 6.5 m                        | 9.2 m                        |
| 35°   | 6.8 m                        | 9.8 m                        |
| 40°   | 7.3 m                        | 10.4 m                       |
| 45°   | 7.9 m                        | 11.3 m                       |

For other plot radii or slopes, use the following correction:

$$\text{plot radius on slope} = \text{plot radius on level ground} \times 1 / \cos(\text{slope})$$

## References

- Woodland Carbon Code. (2026). Survey Protocol for Woodland Carbon Code projects, version 3.0.1. [woodlandcarboncode.org.uk](https://woodlandcarboncode.org.uk)
- Heiðarsson, L., Pukkala, T. and Snorrason, A. (2026). Growth, biomass and stem volume models for downy birch in Iceland. *Icelandic Agricultural Sciences* 39, 3–22.
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